Avocado information kit

Reprint – information current in 2001

REPRINT INFORMATION – PLEASE READ!

For updated information please call 13 25 23 or visit the website www.dpi.qld.gov.au

This publication has been reprinted as a digital book without any changes to the content published in 2001. We advise readers to take particular note of the areas most likely to be out-of-date and so requiring further research:

- Chemical recommendations—check with an agronomist or Infopest www.infopest.qld.gov.au
- Financial information—costs and returns listed in this publication are out of date. Please contact an adviser or industry body to assist with identifying more current figures.
- Varieties—new varieties are likely to be available and some older varieties may no longer be recommended. Check with an agronomist, call the Business Information Centre on 13 25 23, visit our website www.dpi.qld.gov.au or contact the industry body.
- Contacts—many of the contact details may have changed and there could be several new contacts available. The industry organisation may be able to assist you to find the information or services you require.
- Organisation names—most government agencies referred to in this publication have had name changes. Contact the Business Information Centre on 13 25 23 or the industry organisation to find out the current name and contact details for these agencies.
- Additional information—many other sources of information are now available for each crop. Contact an agronomist, Business Information Centre on 13 25 23 or the industry organisation for other suggested reading.

Even with these limitations we believe this information kit provides important and valuable information for intending and existing growers.

This publication was last revised in 2001. The information is not current and the accuracy of the information cannot be guaranteed by the State of Queensland.

This information has been made available to assist users to identify issues involved in the production of avocadoes. This information is not to be used or relied upon by users for any purpose which may expose the user or any other person to loss or damage. Users should conduct their own inquiries and rely on their own independent professional advice.

While every care has been taken in preparing this publication, the State of Queensland accepts no responsibility for decisions or actions taken as a result of any data, information, statement or advice, expressed or implied, contained in this publication.

Queensland Government

Key ISSUES

This section contains more detailed information on some important decision-making areas and information needs for avocados. The information supplements the growing and marketing guidelines in Section 3 and should be used in conjunction with it. The information provided is not designed to be a complete coverage of the topic but are the key points that need to be known and understood. Where additional information may be useful, we refer you to other sections of the kit. Symbols on the left of the page will help you make these links.

Success in avocado growing—an overview

Long-term success in avocado growing requires careful management of many different issues. These fall broadly into three categories: selecting the right site to minimise the potential losses from root rot disease; managing the business to maximise returns and minimise costs; and carefully managing crop production to ensure the maximum yield of quality fruit. This subsection provides an overview of these three key areas. Detail on each issue is then provided in subsequent subsections.

A snapshot of the key issues

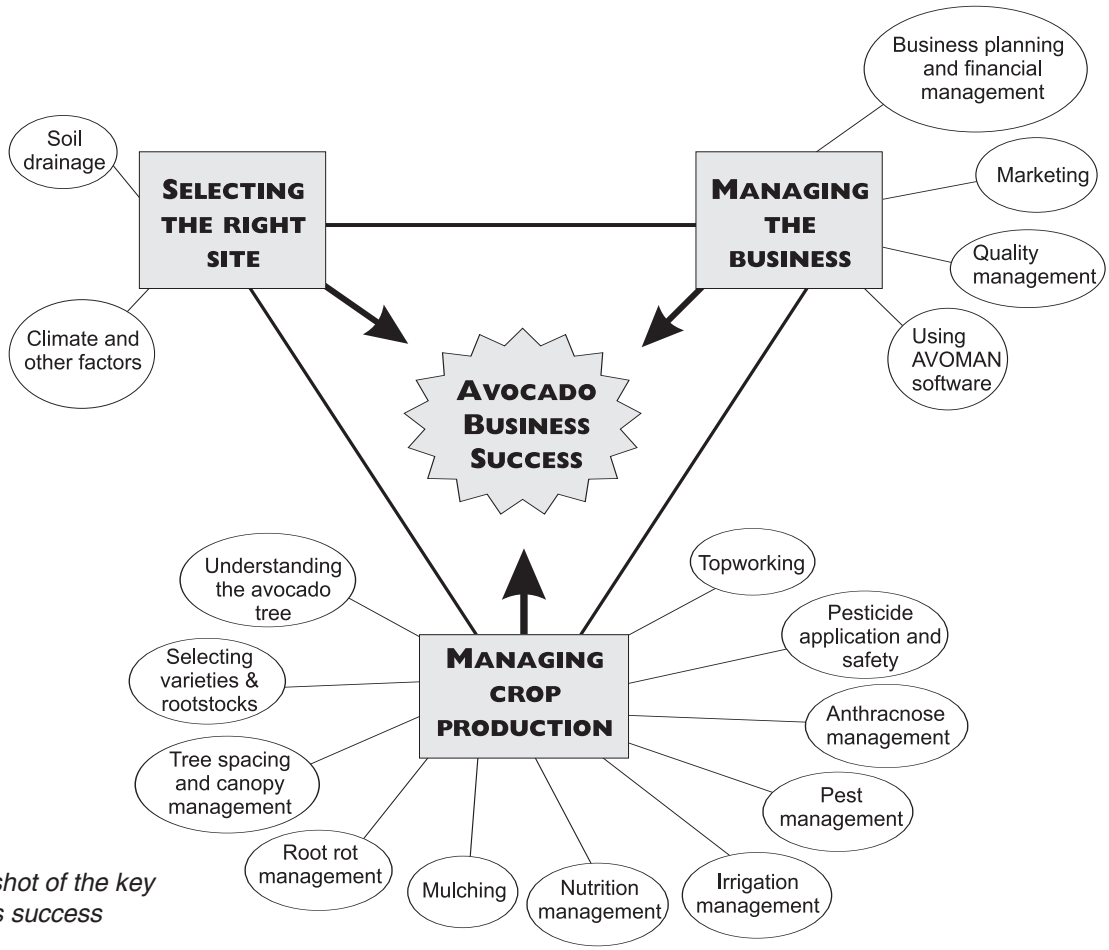


***Figure 1**. A snapshot of the key issues in business success*

Selecting the right site

Phytophthora root rot is the most destructive disease in subtropical horticulture. The avocado tree is so susceptible to this disease that all steps have to be taken to minimise its effects. The first and most important is to select an orchard site that has excellent soil drainage. See page 5 for details.

Managing the business

To enjoy long-term financial success, avocado growing should be considered a business, not a lifestyle. Thinking and planning about finance and marketing is as important as thinking and planning about production. Treating an avocado enterprise as a business involves several important steps:

Business planning and financial management. Before you start an avocado orchard, do a thorough business plan. This will show you where the main risks lie and where you will have to focus special effort to keep your business viable. Review the plan regularly to ensure your business is in line with your objectives. Accurately record all farm information so that legal requirements are satisfied and financial performance can be measured from year to year. See page 10 for details.

Marketing. Be driven by the market, not by tradition or what other people have told you. Investigate existing and potential markets and set up your business to meet their requirements. Consider marketing alliances to give you access to different markets and to increase your marketing strength. Development of a marketing plan will ensure you are considering appropriate market issues. See page 23 for details.

Quality management. Aim for quality at all times. Once you have established market quality requirements, make sure your production and marketing system delivers that quality. Development of quality standards and their assurance through implementation of a quality management system is the only guaranteed way of achieving quality. See page 29 for details.

AVOMAN and AVOINFO software. These computer software packages were developed specifically for Australian avocado growers. Use AVOMAN to record farm information, guide management decisions and monitor production performance. Use AVOINFO to source required information on all aspects of avocado production and marketing. See page 34 for details.

Managing crop production

Once you have determined market requirements and quality standards, the aim is to maximise the production of fruit that meets these standards. This requires several important steps:

Understanding the avocado tree. Knowledge of how the tree grows and produces fruit is an essential first step in managing crop production. See page 39 for details.

Selecting varieties and rootstocks. Although there is a relatively limited range of commercial varieties, it is important that you select varieties that the market wants and those that suit your location. As rootstocks can have a significant effect on tree performance and fruit quality, rootstock selection is also important, particularly as this cannot be changed once trees are planted. See page 44 for details.

Tree spacing and canopy management. Avocados can rapidly grow into large trees, reducing light penetration, thus affecting fruit production and quality. Large trees are more difficult to manage and cost extra for spraying and harvesting. To maintain a productive and efficiently managed orchard, carefully choose tree spacings and manage the canopy through pruning and tree thinning. See page 58 for details.

Root rot management. Because of the importance of Phytophthora root rot in avocados, a major emphasis is needed to keep it under control. This involves an integrated management program of seven main components: good soil drainage, orchard quarantine, tolerant rootstocks, disease-free nursery trees, balanced nutrition and irrigation, surface mulching and judicious use of chemicals. See page 65 for details.

Mulching. The avocado has a shallow root s ystem adapted to feeding from surface litter. This makes trees very susceptible to moisture stress and other related problems. Mulching provides many benefits and is vital for long-term orchard health and productivity. See page 70 for details.

Nutrition management. Correct nutrition is vital for maximising fruit yield and quality and for keeping the tree in a healthy condition in the presence of Phytophthora root rot. Pay particular attention to the management of nitrogen, boron, calcium, zinc and soil pH. See page 76 for details.

Irrigation management. For a tree of its size, the avocado has a poorly developed root system. This is because the roots have few root hairs, making water uptake inefficient. An efficient watering system, managed effectively through soil moisture monitoring, is very important. See page 98 for details.

Pest management. Several insect pests, some of which are capable of significantly reducing fruit yield and quality, can attack the avocado tree. Pest management requires regular monitoring of the orchard to determine the presence and severity of pest infestations, and the timely and thorough application of pesticides. See page 112 for details.

Anthracnose management. After Phytophthora root rot disease, anthracnose is the next most important disease of avocados. It is a serious problem for the industry because symptoms generally only show at the consumer end of the chain when fruit ripens. It has consequently become the major issue of concern for avocado consumers. To ensure consumer confidence is maintained, all growers have a responsibility to properly manage anthracnose. See page 127 for details.

Pesticide application and safety. Although there have been significant advances in the use of integrated pest and disease management systems, current technology still depends substantially on the use of chemical pesticides. There are two important aspects of responsible use of chemicals. The first is efficient application so that the effect of each spray is maximised, thereby reducing the number of sprays that may be necessary. The second is safety in use and application to minimise any impact of chemicals on operators, farm workers and the community. See page 130 for details.

Topworking. Preferred avocado varieties will change with time, either because of changing consumer preferences or the availability of new varieties with better marketing and production performance. When this happens, you have a choice of replanting with new trees or topworking existing trees to the new varieties. Topworking provides a faster turnaround to productive returns. See page 136 for details.

Selecting the right site

Root rot disease, caused by the fungus Phytophthora cinnamomi*, is the most destructive disease in subtropical horticulture. It affects over 900 plant species including avocado, pineapple, macadamia, stonefruit and a wide range of ornamentals.*

Of all the affected species, avocado is perhaps the most susceptible and several steps have to be taken to minimise its effects. The first and most important is to select an orchard site that has excellent soil drainage. This section explains how this is done. Other site issues such as climate and water availability are also important, but soil drainage takes priority.

Root rot management
This section page 65

Why soil drainage is so important

Phytophthora cinnamomi, the cause of avocado root rot, belongs to a group of fungi referred to as water moulds. These fungi require free water to produce spores and infect roots. Zoospores, the main spore type produced, are tiny swimming spores that are strongly attracted to avocado roots by root exudates. The more soil water, the more spores are produced, and the easier they move through the soil water to the avocado roots. Soils on which avocados are grown need to have sufficiently good internal drainage so that excess free water is not retained in the root zone for any length of time. This is particularly important in high rainfall areas where the volume of free water moving through the soil is much greater.

In soil, it is important to distinguish between excess free water and available soil moisture. The avocado tree requires moisture to grow and produce and, in what might appear to be a contradiction, it requires a plentiful and regular supply of moisture. This is because avocado roots have few root hairs, making water uptake relatively inefficient. But there is a big difference between plentiful moisture and excess free soil water.

Plentiful moisture refers to a state where, after drainage of water through the soil profile, water adheres to the soil particles and air fills the gaps (or soil pores) between the soil particles. On the other hand, excess free soil water refers to a state where the downward drainage process is impeded, leaving larger quantities of 'free' water and little air in the soil. This is the condition where zoospores of the Phytophthora fungus thrive and move readily through the soil.

Besides the risk of Phytophthora infection, there is another important reason for good drainage. Avocado roots are extremely susceptible to waterlogging, regardless of whether the root rot fungus is present or not. Flooding or waterlogging of the soil usually kills avocado roots within 48 hours.

What is well-drained soil?

To avoid the risk of Phytophthora root rot and waterlogging, avocado soils need to have free drainage to a depth of at least:

- 1 m (where rainfall is less than 700 mm/year);
- 1.5 m (where rainfall is 700 to 1500 mm/year);
- 2 m (where rainfall is over 1500 mm/year).

Free drainage means free water does not accumulate within that prescribed depth. The emphasis here is on accumulation because, in practice, heavy rain falling at 25 mm per hour will saturate most soils, making them fairly wet. However, as long as the soil drains freely to below the prescribed depth and it does not remain saturated except for very short periods, root damage will be minimised.

Soils at risk of an excessive accumulation of water include those with impervious clay or rock subsoil layers, and those with an overall high clay content. These soils are a problem because either the impervious layers or the high clay content slow drainage of water, allowing the water to accumulate within the root zone.

Before we show how drainage can be properly assessed, there are three important misconceptions that should first be clarified.

Misconception 1: Sloping land is well drained. Although a slope helps to shed surface water and reduce the quantity that infiltrates into the soil, it does not mean the soil is well drained. Some of the worst drained soils are on steep slopes, while some of the best drained soils are on flat ground. Internal drainage characteristics of the soil are important, not just the slope.

Misconception 2: Poorly drained land can be improved to make it suitable for avocados. Although subsurface drainage pipes will improve soil drainage, experience has shown that this generally only provides a temporary solution. The system may cope under normal rainfall, but it often fails during heavy rainfall. Also, subsurface drainage is expensive to install and maintain. Mounding of the tree rows before planting is appropriate practice where the depth of well-drained soil is only marginally less than required. However, where the depth of well-drained soil is significantly less than required, mounding is not a long-term solution. We recommend you plant other crops less susceptible to root rot and waterlogging.

Misconception 3: With new root rot disease controls such as phosphonate fungicides, soil drainage is less important. The new technology has made root disease control more effective and reliable, but it does not lessen the importance of good soil drainage. Avocado trees can die very quickly from waterlogging, irrespective of whether root rot is present or not. Also, it is important to minimise dependency on any one control method such as chemicals. The only safe long-term option is to use an integrated approach, of which one important element is the selection of well-drained soils.

Assessing soil drainage

The only way to assess soil drainage is to dig holes down through the soil profile to the prescribed depth (1 to 2 m depending on rainfall). Holes need to be dug on a grid pattern across the intended planting area. The distance between inspection sites depends on the variation in topography and soil, but as a rough guide a hole every 30 to 50 m is sufficient.

For a small property, the holes can be dug by hand with a soil auger (Figure 2) or posthole digger. Alternatively, a backhoe can be hired. For a larger property, it is best to hire a contractor with a motorised truck-mounted auger.

At each site, use an auger to drill a hole to the prescribed depth and lay out the soil on the ground in a line corresponding toits approximate depth (Figure 2).

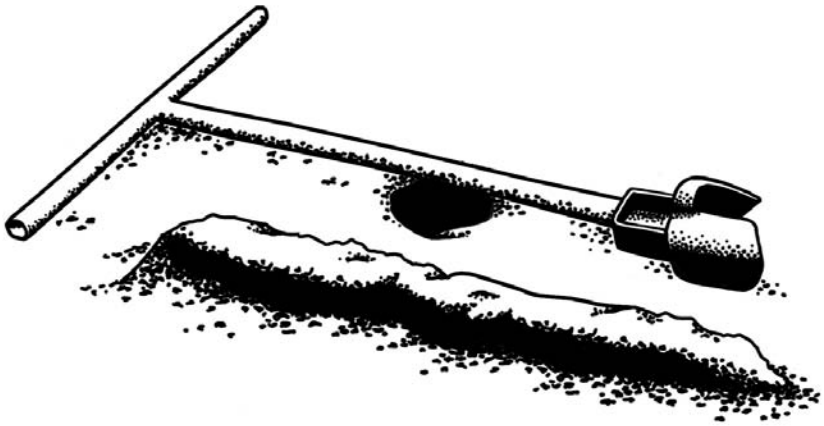


***Figure 2**. A soil auger suitable for soil assessment on small properties. The diagram shows how the soil from the hole is laid out in a line corresponding to the approximate soil depth*

The soil properties, such as texture, colour and presence of rock or clay layers, are then described (see below). Record the data by developing a soil map of the property. This is a general map of the property showing the main features and on which you record the soil data from each inspection site. It is also useful to note other block features such as aspect and slope. These will be useful later in designing windbreaks and irrigation layouts. When the data has been collected, the boundaries of the major soil types can be drawn on the map. This is then used to determine the size and boundaries of different orchard blocks, the need for mounding or subsurface drainage, and irrigation management issues.

Soil properties

The most important soil property to measure at each inspection site is soil texture. Soil texture refers to the 'feel' of the soil and measures the relative amounts of sand and clay present. Soils are loosely classified as sands, sandy loams, loams, clay loams and clays. The best way to assess soil texture is by a ribbon and rod/ring test:

1. Take a small handful of the soil to be tested and remove any stones.
2. Slowly wet the soil, kneading it thoroughly until you have a ball of soil that is moist but not wet and sticky. Note the feel of the moist soil as you knead it.

3. Holding the ball of moist soil in your hand, gradually press out a ribbon or tongue of the soil between your thumb and bent forefinger (Figure 3). Note how long the ribbon extends before it breaks. Repeat this several times and you will find that the ribbon breaksoff into fairly consistent lengths.

***Figure 3**. Ribbon test for assessing soil texture*

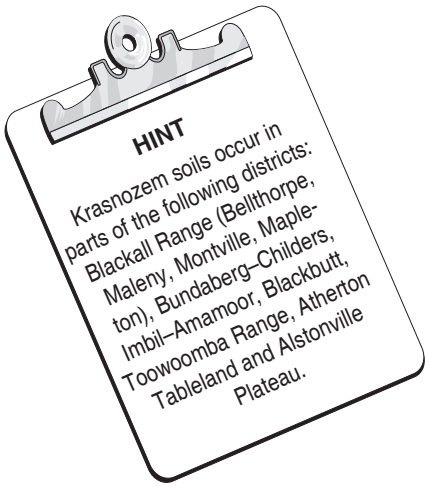
4. Now try rolling the soil into rods and if this is possible try bending this rod into a ring. Use Table 1 to determine the soil texture.

***Table 1**. Soil texture classes based on feel, ribbon length and rod/ring test*

Soil texture	Feel	Ribbon length	Rod and ring test
Sand	Does not stick together, has a gritty feel	Under 15 mm	Will not roll into rods, breaks easily
Sandy loam	Sticks together, friable, has gritty feel	15 to 25 mm	Will not roll into rods, breaks easily
Loam	Sticks together, friable, sand grains cannot be felt	25 mm	Will not roll into rods, breaks easily
Clay loam	Sandy grains cannot be felt, but soil can be moulded	25 to 50 mm	Rolls into a rod, but cannot be turned into a ring without cracking
Clay	Can be moulded, the heavier the clay the stiffer it is	Over 50 mm	Rolls into a rod easily. Can be turned into a ring without a lot of cracking

Do a soil texture test with soil from at least the middle and bottom of the hole, and preferably wherever the colour or appearance of the soil changes significantly.

Where the soil texture falls within the sand, sandy loam or loam categories through to the prescribed depth, the soil drainage at that site can be considered generally suitable for avocados. A clay or clay loam reading means the drainage at that site may be questionable. If clay or clay loam occurs in the bottom of the profile only, mounding may be necessary. If clay or clay loam occurs within the upper part of the profile, it usually means that site is generally unsuitable for avocados.



However, there is one exception. Krasnozem soils (red, well-structured clay soils) test out as light clay or clay loam in the upper part of the profile and medium clay in the lower part of the profile. Despite this, they have very good crumb structure, which means that water infiltration and drainage is good. Provided the soils are deep enough and have no large rocks (floaters) within the profile, they are suitable for avocado production.

Other soil properties to note are colour and the presence of rock or 'hardpan' layers. A 'hardpan' layer is a hardened or cemented layer in the profile that will not allow water to pass through freely. Mottled colours (blotches or streaks of different colour to the normal soil colour) are generally an indication of poor drainage. Note the depth at which this occurs.

Rock or hardpan layers are generally difficult to drill through with an auger. To assess their effects on drainage, do an infiltration test. This involves drilling an auger hole to the depth of the obstruction, pouring in about 5 L of water, and recording how long it takes for the water to soak away. To be safe for avocados, the water should drain away within one hour. This test is only valid where the soil is moist right down the profile, that is either after good rain or after the hole has been previously filled with water and allowed to drain completely.

Site issues other than drainage

Other issues are also important in selecting the right site. Here is a summary of them.

Climate. Frost-free areas are preferred. During the flower development period from budbreak to the point of flowering, night temperatures should not exceed 15°C (5 to 10°C preferred). Day temperatures should not exceed 25°C (20°C preferred). During flowering, (varies from August–September on the Atherton Tableland to October–November in south-west Western Australia), night temperatures should not fall below 10°C, particularly for temperature-sensitive varieties such as Shepard, Fuerte and Sharwil.

Slope and aspect. Flat ground or slopes of less than 15% are preferred to minimise erosion and enable safe operation of machinery. Aspects protected from the main prevailing winds are preferred to minimise fruit rub damage. In the cooler southern growing areas, slopes with a northerly aspect are preferred to maximise light interception and spring temperatures.

Water availability and quality. Irrigation is essential in most areas, particularly from August to April. Depending on rainfall, climate and soil type, a water storage reserve of between 4 and 18 ML/ha of orchard is recommended to maintain production in a dry year. As avocados are sensitive to salt in the irrigation water, water salinity should not exceed 0.6 deciSiemens per metre (dS/m) with a chloride content less than 80 mg/L.

Managing the business:
Business planning and financial management

The first step in managing the business is to treat it like a business. This involves developing a business plan, carefully recording farm information so you can measure progress against the business, and monitoring financial performance so you can regularly review costs and returns.

Business planning

All businesses need a plan to be successful. A plan helps you focus on what the business hopes to achieve. An avocado business plan needs to be drawn up for 5 to 10 years and should be reviewed and modified annually, to ensure it reflects your current business objectives.

A typical business plan includes the following sections:

1. Goals and objectives
2. Situation analysis—SWOT (Strengths, Weaknesses, Opportunities, Threats)
3. Action plan/implementation plan
4. Budget and cash flow
5. Control plan

As marketing is a key component of the avocado business, the business should include a marketing plan. This should focus on the supply chain and the grower's position in it. A typical marketing plan includes the following sections:

1. Current marketing situation
   - domestic
   - export
   - competitive situation
2. Opportunity and issue analysis
   - SWOT analysis (Strengths, Weaknesses, Opportunities, Threats), including an analysis of the grower's competitive position
   - Issue generation and priorities

3. Objectives
   – financial
   – marketing
4. Marketing strategy
   – pricing
   – product description and lines
   – positioning and segments
   – distribution strategy
   – sales
   – advertising and promotion strategy
   – research and development
5. Action program and control
6. Budget

A wide range of professional services is available to help you in developing business and marketing plans. These include banks, accountants, financial advisers and consultants. You should be prepared to make a modest investment to ensure you have a realistic business plan for your enterprise.

Recording farm information

Accurate and ordered recording of information on the farm is essential for good business management. It is also a legal requirement for taxation purposes, chemical use legislation, Workplace Health and Safety audits, approved supplier accreditation, quality assurance certification systems and Interstate Certification Assurance (ICA) protocols. Types of information that may be recorded include:

- preharvest (pest and disease monitoring records, spray program, labour inputs, leaf and soil analysis, soil moisture monitoring, fertiliser and irrigation schedules);
- postharvest (labour, picking, packouts, handling and storage logs, chemical usage);
- quality management records.

This information is used to satisfy legal requirements, compare performance from year to year and to establish best farm practice. It also supports the development and updating of your business plan. It can be recorded on a computer where information can be quickly accessed and compared, in books, or on forms and filed in a filing cabinet. The AVOMAN farm recording computer package is one way f recording and using this information (Figure 4).

IMPORTANT—USE OF ENDOSULFAN

It is a legal requirement that all growers using the pesticide endosulfan maintain a record of each application. It is the responsibility of the grower to collect (either directly or from a person on his/her behalf) and record all of the information required in a special Endosulfan Spray Record*. The record requires the completion of information on the farm and the name of person applying, crop and pest details, weather conditions at application, and detailed application information. Growers may use their own computer-generated forms or special forms available from the National Registration Authority (NRA) or other chemical agencies.*

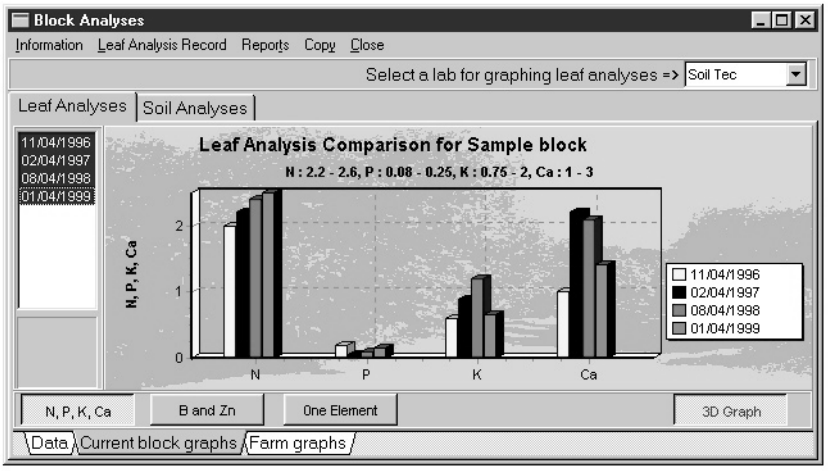


***Figure 4**. Example of AVOMAN farm recording software*

Financial management

Accurate recording of financial inflows and outflows ensures that the true financial situation of the business is known at all times. This is important for decision-making. Accurate recording of inputs and outputs means including all costs such as family labour, loan interest and depreciation.

There are many financial recording packages on the market. Consult your accountant or financial adviser for details of packages that suit your purposes as well as complying with taxation requirements.

To help in understanding financial management, two economic analyses of avocado growing are given here, the first for a Shepard orchard in the Mareeba–Dimbulah Irrigation Area, and the second for a Hass orchard at Nambour. It is important to note the different assumptions for each.

Economic analysis 1: Shepard at Mareeba

(Information courtesy of Julie Miller, formerly DPI, Mareeba)

This study analyses a model or hypothetical farm of 20 ha of Shepard avocados grown in the Mareeba–Dimbulah Irrigation Area in North Queensland. It provides the following details:

- Variable costs in the eighth year when at full production (includes growing, harvesting and marketing costs).
- Fixed costs for a 20 ha orchard (includes an allowance for permanent labour and the farmer's own labour, administration costs, electricity, depreciation).
- The capital costs for a 20 ha orchard over 20 years.
- Annual whole orchard profit and loss statement at orchard maturity. This includes a gross margin (the difference between the gross income and the variable or operating costs).
- Discounted cash flow analysis to determine the annual cost of production and profitability. This is a technique used widely to analyse profitability for long-term tree crops where costs and benefits occur over a long period. The technique reduces the time stream of costs and benefits to an equivalent amount of today's dollars. That amount is known as the

present value of the future stream of costs and benefits. The present values are calculated using compound interest and a specified discount rate (in this case 8%). The Net Present Value (NPV) is the difference between the present value of the benefits and the present value of the costs.

- Sensitivity analysis for the discounted cash flow showing the effect of different prices and yields.

Assumptions

Main assumptions used in this analysis:

- The hypothetical avocado orchard consists of 20 ha of Shepard trees at a spacing of 10 m x 7 m. Tree density is 140 trees/ha allowing for three losses per hectare (20 ha x 140 trees/ha = 2800 trees). Buildings, roads, windbreaks, drains, dams and non-arable land, occupy an additional 4 ha. The avocados represent half of the enterprise, the other half being mango production. Some of the capital costs (below) are shared equally with the mango enterprise.
- The orchard is considered to be at steady state full production in the eighth year.
- Mature tree yields are considered to be approximately 15 trays (5.6 kg trays)/tree (12 t/ha). Fruit is marketed in Brisbane (50%) and Sydney (50%). Average prices are $12.87/tray in Brisbane and Sydney, less commission, freight, levies and insurance.
- 10% of the harvested fruit is rejected in the pack house.
- 90% of marketable fruit is packed in 5.6 kg trays with the remainder in 10 kg boxes.
- Capital equipment is bought new, except for a tractor and utility which are bought second-hand.
- Grower does own packing and marketing.
- Machinery operation includes fuel and oil costs only.
- No permanent labour is used. Casual labour is employed for pruning, harvesting and packing to supplement family labour of the owners.
- The orchard is well managed.
- A project life of 20 years is used with a real discount rate of 8% to calculate the net present value (NPV).
- Figures used in the analysis were current as of April 2000.

Variable costs at full production

Item	No./yr	Units/ha	Unit	$/unit	$/ha
Machinery operation					
Spreading fertiliser	6	0.4	hour	6.94	17
Pest/disease spraying	19	0.4	hour	6.94	53
Slashing	6	0.75	hour	1.38	6
Pruning and injecting					
Pruning	1	35	hour	13	455
Phosphonate fungicide injection	2	8.4	hour	13	218
Fertiliser and mulch					
CK77S	3	224	kg	0.49	329
Potassium nitrate	1	28	kg	0.97	27

Item	No./yr	Units/ha	Unit	$/unit	$/ha
Zinc sulphate (by hand)	1	112	kg	1.09	122
Solubor	4	21	kg	3.99	335
Dolomite/gypsum	1	560	kg	0.10	56
Mulch	0.333	560	bales	2.50	467
Herbicide					
Roundup® dry	3	1.5	kg	12.77	57
Insecticide					
Endosulfan	7	2.1	L	10.85	160
Chlorpyrifos	4	1.4	L	12.85	72
Fenbutatin oxide	2	0.7	L	91.62	128
Dimethoate	3	1.54	L	8.23	38
Fungicide					
Kocide®	11	2.94	kg	7.64	247
Fosject®	2	25.2	L	2.09	105
Irrigation (includes pumping, allocation and consumption costs)	n.a.	8	ML	39.08	313
TOTAL PREHARVEST COSTS					**3205**

Harvesting, marketing & refrigerated road transport	Trays/hr	Units/ha	Unit	Cost/unit	$/ha
Picking	11	196	hour	13	2,548
Packing trays (labour)	17	103.8	hour	13	1,349
Packing bulk boxes (labour)	12	9.1	hour	13	118
Packaging (trays)		1,764	tray	1.87	3,299
Packaging (bulk boxes)		110	box	1.72	189
Lebaycid® and Sportak®		1,874	tray	0.06	118
Pallet hire		1,874	tray	0.05	98
Pallet tape/corner pieces/layer pads		1,874	tray	0.07	137
Commission (12.5%)		1,874	tray	1.61	3,154
Levies (trays)		1,764	tray	0.23	406
Levies (bulk boxes)		110	box	0.38	42
Freight to Brisbane		882	tray	0.76	670
		55	box	1.02	56
Freight to Sydney		882	tray	1.28	1,129
		55	box	1.71	94
TOTAL HARVESTING and FREIGHT COSTS					**13,407**
TOTAL VARIABLE COSTS					**16,612**

Fixed costs for the 20 ha orchard

Item	Amount ($/year)*
Owner/operator labour	22,700/2 = 11,350
Casual labour (5 days/week)	22,700
Fuel and oil for utility and farm motorbike	2,500/2 = 1,250
Electricity for equipment, lighting and cold room	8,000/2 = 4,000
Repairs and maintenance	15,000/2 = 7,500
Administration	8,800/2 = 4,400
TOTAL FIXED COSTS	**51,200**

* Fixed costs divided evenly between avocado and mango enterprises

Capital costs for the 20 ha orchard over 18 years

Item	Year/s of purchase	Cost ($)
Land (20 ha x $2250/ha), assumes developed and includes access to irrigation	0	45,000
Tractor (90HP)	0	72,500
Tractor (18HP) *	0	25,000
Land preparation	0	14,580
Pumps, mains, sub-mains, unspecified irrigation equipment #	0	48,750
Power to pump #	0	500
Small dam (5 ML) #	0	12,500
Water nominal allocation (@ $225/ML)	0	27,000
Trees and planting labour	0	31,800
Utility *#	0	7,500
Slasher	0	5,000
Herbicide sprayer	0	2,000
Trailer x 2 #	0	2,000
Workshop and office equipment #	0	2,500
Picking bags (10) @ $50 #	1	250
Cold room #	1	15,000
Packing shed with grader #	1	30,000
Storage shed #	1	5,000
Electricity to sheds #	1	2,500
Pruning equipment #	1	750
Replacements for irrigation components #	1	375
Fork-lift *#	3	4,000
Bins (30) @ $165 #	3	2,475
Air blast sprayer	3	18,000
Pruning equipment replacement #	5	438
Cherry picker	5	22,500
Replacements for irrigation components #	6	375
Herbicide sprayer	10	1,800
Utility *#	10	6,375
Slasher	10	4,500
Pruning equipment replacement #	10	427
Replacements for irrigation components #	11	375
Spray pump replacement	13	4,875
Tractor (18 HP)	15	22,500
Small dam (5 ML) # clean out and repair	15	12,500
Spray machine pump replacement	15	5,000
Trailer x 2 #	15	1,800
Pruning equipment replacement #	15	427
Workshop and office equipment	15	2,125
Replacements for irrigation components #	16	375
Fork-lift #	18	3,400
Bins (30) @ $165 #	18	2,425
Picking bags (10) @ $50 #	18	238
TOTAL CAPITAL COSTS (including land)		**467,605**

* Bought second-hand

Only half the value of the capital item was used in this analysis, as it was assumed the other half would be covered by other operations on the model farm, e.g. mango production

Profit/loss statement for 20 ha orchard (NPV) 8th year

Item		$/farm/yr	$/ha	$/tray
GROSS INCOME		**504,580**	**25,229**	**12.87**
Variable costs				
Machinery operation		1,520	76	0.04
Pruning and injecting		13,460	673	0.34
Fertiliser and mulch		26,720	1,336	0.68
Herbicide		1,140	57	0.03
Insect control		7,960	398	0.20
Fungicide		7,040	352	0.02
Irrigation		6,260	313	0.16
Harvesting and marketing		268,140	13,407	6.84
TOTAL VARIABLE COSTS		**332,240**	**16,612**	**8.48**
Fixed costs				
Owner/operator labour		11,350	567.50	0.29
Casual labour (5 days/week)		22,700	1,135	0.58
Fuel and oil		1,250	62.50	0.03
Electricity		4,000	200	0.10
Repairs and maintenance		7,500	375	0.19
Administration		4,400	220	0.11
Capital costs	(5% of total)	25,978	1,299	0.66
TOTAL FIXED COSTS		**77,178**	**5,266**	**2.69**
TOTAL COSTS		**409,418**		
GROSS MARGIN		**172,340**		
GROSS MARGIN/ha			**8,617**	
GROSS MARGIN/tray				**4.39**

Discounted cash flow analysis for 20 ha orchard

Year	Yield (trays/year)	Receipts ($)	Operating costs ($)	Fixed costs ($)	Capital costs ($)	Annual cash flow ($)	Discounted annual cash flow ($)	Discounted accumulative cash flow ($)
0					299,630	-299,630	-296,630	-296,630
1	0	0	11,968	45,577	53,875	-111,420	-105,113	-401,743
2	1,399	18,014	31,212	47,452		-60,650	-53,978	-455,721
3	4,200	54,062	75,121	49,327	24,475	-94,861	-79,646	-535,367
4	11,199	144,159	105,485	51,202		-12,528	-9,923	-545,290
5	16,800	216,249	154,491	51,202	22,938	-12,382	-9,252	-554,542
6	28,000	360,413	242,902	51,202	375	65,934	46,482	-508,061
7	33,600	432,498	282,375	51,202		98,921	65,789	-442,272
8	39,200	504,582	332,389	51,202		120,991	75,912	-366,360
9	39,200	504,582	332,389	51,202		120,991	71,615	-294,746
10	39,200	504,582	332,389	51,202	13,102	107,889	60,245	-234,501
11	39,200	504,582	332,389	51,202	375	120,616	63,539	-170,961
12	39,200	504,582	332,389	51,202		120,991	60,219	-110,832
13	39,200	504,582	332,389	51,202	4,875	116,116	54,440	-56,392
14	39,200	504,582	332,389	51,202		120,991	53,515	-2,878
15	39,200	504,582	332,389	51,202	44,352	76,639	34,065	31,188
16	39,200	504,582	332,389	51,202	375	120,616	47,480	78,668
17	39,200	504,582	332,389	51,202		120,991	44,932	123,600
18	39,200	504,582	332,389	51,202	6,063	114,928	40,264	163,864
19	39,200	504,582	332,389	51,202		120,991	39,989	203,853
20	39,200	504,582	332,389	51,202		120,991	37,726	241,579
NPV	**299,073**	**3,849,667**	**2,617,127**	**577,059**	**413,901**			
Av/farm/year	**26,075**	**335,632**	**228,173**	**50,311**	**36,086**			
Av/tray		**12.87**	**8.73**	**1.93**	**1.38**			
Av/tree		**119.87**	**81.48**	**17.97**	**12.89**			

The analysis shows an internal rate of return (IRR) of 9.54% with a peak overdraft of $554 542 in the fifth year. Annual expenses exceed annual income until the sixth year. The payback period, or the time required for accumulated income to exceed accumulated expenses, is 15 years. Put another way, it would take 15 years to recover the initial project outlay.

Sensitivity analysis per hectare ($/ha/year) showing the effect (based on discounted cash flow) of different prices and yield on profit

Yield (tray equiv./tree)	1st grade price ($/tray)					
	8	10	12	14	16	18
6	-$115,366	-$99,475	-$83,585	-$67,694	-$51,803	-$35,913
8	-$108,637	-$87,593	-$66,549	-$45,505	-$24,461	-$3,417
10	-$101,909	-$75,711	-$49,514	-$23,316	$2,882	$29,079
12	-$95,180	-$63,829	-$32,478	-$1,127	$30,224	$61,575
14	-$88,451	-$51,947	-$15,442	$21,062	$57,566	$94,071
16	-$81,722	-$40,065	$1,593	$43,251	$84,909	$126,567
18	-$74,994	-$28,182	$18,629	$65,440	$112,251	$159,062
20	-$68,265	-$16,300	$35,664	$87,629	$139,594	$191,558

Reference for further reading and research: *Growing Shepard Avocados in the Mareeba–Dimbulah Irrigation Area—an Economic Perspective* by A. W. Hinton, in Choices Seminar Series No 11—Avocados (1995), Department of Primary Industries, North Region.

Economic analysis 2: Hass at Nambour

(Information courtesy of Simon Newett, DPI, Nambour)

The second study analyses a hypothetical farm of Hass avocados growing at Nambour in south-east Queensland. It provides the following details:

- variable costs;
- fixed costs;
- capital costs;
- gross margin analysis for the sixth year (the difference between the gross income and the variable or operating costs).

Assumptions

Main assumptions used in this analysis:

- Avocados are the only crop grown.
- The hypothetical orchard consists of 20 ha of Hass avocado trees. An additional 4 ha is occupied by buildings, roads, windbreaks, drains, dams and non-arable land.
- Trees are planted at a spacing of 8 m x 4 m (310 trees/ha allowing for 2.5 losses per hectare), 20 ha x 310 trees/ha = 6200 trees.
- The orchard is considered to be at full production in the sixth year.
- Mature tree yields are considered to be 6.5 trays (6 kg trays)/tree (12 t/ha). Fruit is marketed in Brisbane (30%) and Melbourne (70%). Average prices are $12.87/tray in Brisbane and Melbourne, less commission, freight, levies and insurance.

- 10% of fruit harvested is rejected in the pack house.
- Capital equipment is bought as per the table below.
- Grower does own packing and marketing.
- Machinery costs include fuel and oil costs only; maintenance costs listed as a fixed cost.
- Labour is an opportunity cost, each job's labour cost being shown separately. This is different from the Mareeba Shepard analysis where a lump sum is allocated for family labour and another for casual labour.
- The orchard is well managed.
- Picking rate is equivalent to 30 trays per person per hour.
- Sorting and packing rate is equivalent to 19 trays per person per hour.
- Foliar spray rate is 7 L/tree in the sixth year.
- Figures used in the analysis were current at July 2000.

Establishment costs

Item	Units/ha	Unit	$/unit	$/ha			Total $/ha
				Labour	Machinery	Material	
Green manure crop							
Prepare ground, sow, fertilise, incorporate (labour)	12	hr	15	180			
Prepare ground, sow, fertilise, incorporate (machinery)	12	hr	15		180		
Dolomite/lime (delivered and spread)	2.5	tonne	125			313	
Soil analysis	1	sample	80			80	
Urea	500	kg	0.37			185	
Superphosphate	500	kg	0.28			140	
Seed: 90 kg/ha oats, 4 kg/ha Haifa clover	94	kg	1.10			103	
TOTAL				**180**	**180**	**821**	**1181**
Land preparation							
Survey, mark out and peg (labour)	12	hr	15	180			
Work up ground and mound (labour)	18	hr	15	270			
Work up ground and mound (machinery)	18	hr	50		900		
TOTAL				**450**	**900**		**1,350**
Irrigation							
Trencher for submain	4	hr	50		200		
Control valve, fittings						500	
Submain (32 mm LDPE)	100	m	0.88			88	
Laterals (19 mm LDPE)	1,250	m	0.39			488	
Mini-sprinklers (90 L/hr), riser, and adaptor	312	ea	3			936	
Installation	30	hr	12	360			
TOTAL				**360**	**200**	**2,012**	**2,572**
Establish trees							
Plant trees (10 mins/tree)	52	hr	15	780			
Trees (grafted)	312	tree	12			3,744	
Train/trim (10 mins/tree/yr)	52	hr	15	780			
Metalaxyl treatment 2/yr (material)	31.2	kg	18.80			1,173	
Metalaxyl treatment 2/yr (labour)	2.5	hr	15	75			
Mulch – labour (5 mins/tree/yr)	26	hr	15	390			
Mulch (1 bale/tree/yr)	312	bale	2.25			702	
TOTAL				**2,025**		**5,619**	**7,644**
TOTAL ESTABLISHMENT COSTS/ha				**3,015**	**1,280**	**8,452**	**12,747**

Preharvest variable costs

Item	No./yr	Units/ha	Unit	$/unit	$/ha			Total $/ha
					Labour	Machinery	Material	
Fertiliser (assumes few deficiencies)								
Fertiliser spreading (labour)	3	0.25	hr	15	11			
Fertiliser spreading (machinery). Lime, zinc, superphosphate only; most other fertiliser applied by fertigation	3	0.25	hr	15		11		
Leaf analysis	1	1	analysis	80			80	
Soil analysis	1	1	analysis	80			80	
Superphosphate (broadcast)	1	50	kg	0.28			14	
Urea (fertigate)	8	18	kg	0.37			53	
Potassium sulphate (fertigate)	8	16	kg	0.64			82	
Solubor (fertigate)	14	2	kg	3.20			90	
Zinc sulphate (band)	1	25	kg	1.09			27	
Lime/dolomite (broadcast)	1	1.4	tonne	48			67	
Microgyp® – fine gypsum (fertigated)	6	35	kg	0.45			95	
Foliar boron at flowering (labour)	1	0.75	hr	15	11			
Foliar boron at flowering (machinery)	1	0.75	hr	15		11		
Foliar boron at flowering (material)	1	2	kg	3.20			6	
TOTAL					**22**	**22**	**594**	**638**
Mulching and weed control								
Slashing (labour)	6	0.5	hr	15	45			
Slashing (machinery)	6	0.5	hr	15		45		
Spot spraying (labour)	3	0.5	hr	15	23			
Spot spraying (machinery)	3	0.5	hr	8		12		
Spot spraying – materials (Sprayseed®)	3	2	L	10			60	
Mulch (labour)	1	21	hr	15	315			
Mulch (3 bales/tree/year)	1	936	bale	2.25			2,106	
TOTAL					**383**	**57**	**2,166**	**2,606**
Insect control								
Pest/disease spraying – labour (excl. foliar phosphonate sprays)	18	0.75	hr	15	203			
Pest/disease spraying – machinery (excl. foliar phosphonate sprays)	18	0.75	hr	10		135		
Bait spraying – fruit fly (labour)	18	0.3	hr	15	81			
Bait spraying – fruit fly (machinery)	18	0.3	hr	5		27		
Chlorpyrifos (bait sprays for fruit fly)	18	0.12	L	11.55			26	
Yeast autolysate (bait sprays for fruit fly)	18	0.62	L	6.75			76	
Endosulfan (fruitspotting bug)	8	3.28	L	10.75			282	
Endosulfan (Monolepta)	2	4.34	L	10.75			94	
Mimic® (leafroller)	2	0.19	kg	420			158	
Fenbutatin oxide (tea red spider mite)	2	0.83	L	99.00			164	
White oil (scale insects)	1	34.94	L	2.25			79	
TOTAL					**284**	**162**	**879**	**1,325**
Disease control								
Phosphonate injections (assume injecting all trees) – labour (5 mins/tree)	2	26	hr	15	780			
Phosphonate injections (materials)	2	10.5	L	3.20			67	
Copper oxychloride (anthracnose) – materials (assumes included with insecticide sprays)	14	8.74	kg	3.78			462	
TOTAL					**780**		**529**	**1,309**

Item	No./yr	Units/ha	Unit	$/unit	$/ha			Total $/ha
					Labour	Machinery	Material	
Irrigation								
Irrigation – start pump, fertigate, check sprinklers (labour)	40	0.25	hr	15	150			
Irrigation pumping	40	5.5	hr	1.20		264		
TOTAL					**150**	**264**		**414**
Canopy management								
Manual pruning (labour)	1	52	hr	15	780			
Mechanical pruning (contract)	2	1	hr	100		200		
TOTAL					**780**	**200**		**980**
TOTAL PREHARVEST COSTS/ha		**160 hours of labour**			**2,400**	**705**	**4,168**	**7,272**

Postharvest variable costs

Item	No./yr	Units/ha	Unit	$/unit	$/ha			Total $/ha
					Labour	Machinery	Material	
Harvesting and marketing								
Picking (labour)	2	33.3	hr	15	1,000			
Picking – machinery (cherry picker and carting to packing shed)	2	15	hr	2		60		
Cartons	1	1,800	tray equiv.	1.90			3,420	
Sort and pack (19 trays/hr)	1	1,800	tray equiv.	0.80	1,440			
Postharvest disease control – Sportak®	1	1,800	tray equiv.	0.04			72	
Postharvest insect control – Lebaycid®*	1	1,260	tray equiv.	0.02			25	
Freight	1	1,800	tray equiv.	1.00			1,800	
Levy	1	1,800	tray equiv.	0.30			540	
Agent's commission (12%)	1	1,800	tray equiv.	1.44			2,592	
Pallet hire, tape, corners, etc.	1	1,800	tray equiv.	0.04			72	
TOTAL POSTHARVEST COSTS/ha		**163 hours of labour**			**2,440**	**60**	**8,520**	**11,020**

* 70% of fruit sent to market where fruit fly treatment is a prerequisite

Gross margin analysis

		Labour	Machinery	Material	TOTAL
PREHARVEST COSTS/ha	160 hours of labour	2,400	705	4,168	7,270
POSTHARVEST COSTS/ha	163 hours of labour	2,440	67	8,521	11,020
TOTAL VARIABLE COSTS/ha	**590 hours of labour**	**4,840**	**772**	**12,689**	**18,290**
TOTAL INCOME FROM FRUIT SALES/ha – 10.8 t/ha after rejects of 10% removed in pack house; average price (over all grades) $12.87/tray				23,400	
GROSS MARGIN/ha					**5,110**
TOTAL VARIABLE COSTS FOR 20 ha		**96,800**	**15,440**	**253,780**	**365,800**
TOTAL INCOME FOR 20 ha					**468,000**
GROSS MARGIN FOR 20 ha					**102,200**

Gross margin sensitivity analysis

Gross margin* ($'000s) for 20 ha orchard for a range of yields and fruit prices.

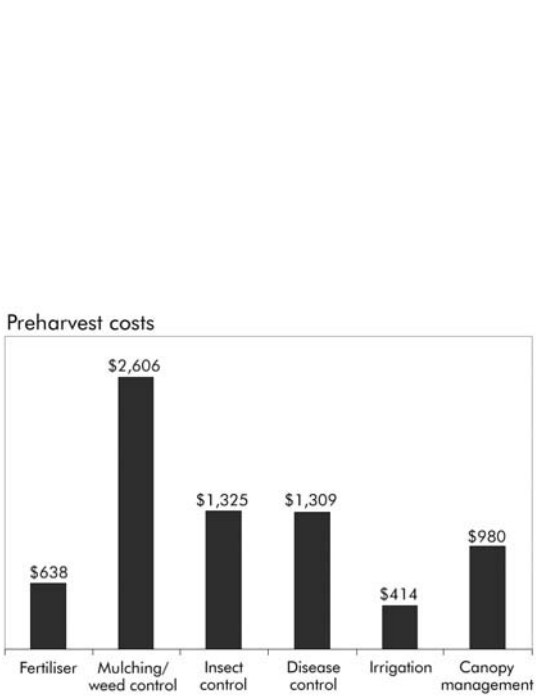
Yield (t/ha)	Average price/tray ($)					
	6	8	10	12	14	16
6	–144	–108	–72	–36	0	36
8	–145	–97	–49	–1	47	95
10	–146	–86	–26	34	94	154
12	–147	–75	–2	69	141	213
14	–147	–63	21	105	189	273
16	–148	–52	44	140	236	332
18	–149	–41	67	175	283	391
20	–150	–30	90	210	330	450

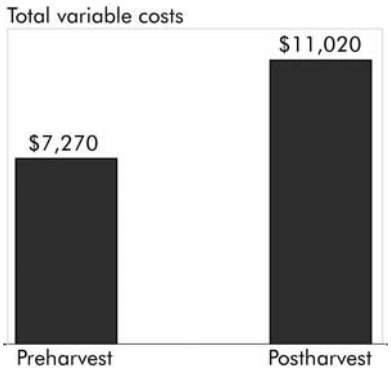
* Gross margin is defined as income less variable costs (i.e. does not account for fixed or capital costs)

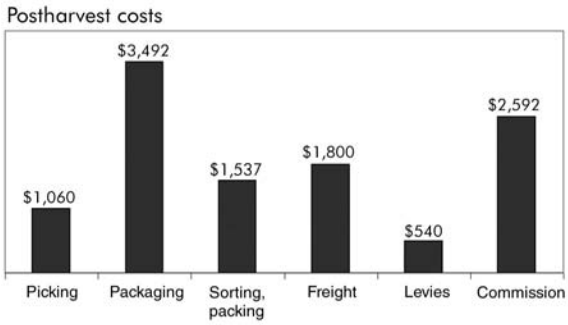
Fixed costs for 20 ha orchard (assumes avocados are only crop)

Item	Total $
Repairs and maintenance (labour)	3,000
Repairs and maintenance (parts)	4,000
Repairs and maintenance (service costs)	4,000
Fuel and oil (non-specialised)	2,000
Electricity (equipment, lighting and cold room)	6,000
Accountant's fee	3,000
Telephone/fax/e-mail	1,000
Registrations	1,300
Insurance	3,000
Management costs (assumes other half of owner's time is spent labouring in operations above)	20,000
Sundry costs	1,000
TOTAL ANNUAL FIXED COSTS for the orchard	**48,300**

Cost distributions/ha







Capital costs for 20 ha orchard over 20 years

Item	Year/s of purchase	Cost ($)
Land (24 ha X $5000/ha), assumes developed	0	120,000
Orchard establishment costs (see above)	0	254,940
Tractor (90HP)	0	72,500
Tractor (18HP) – bought second-hand	0	25,000
Pumps, mains, submains, unspecified irrigation equipment	0	97,500
Power to pump	0	1,000
Dam (50 ML)	0	100,000
Utility – bought second-hand	0	15,000
Slasher	0	5,000
Herbicide sprayer	0	2,000
Trailer x 2	0	4,000
Workshop and office equipment	0	5,000
Picking bags (10) @ $50	1	500
Storage shed	1	10,000
Electricity to sheds	1	5,000
Pruning equipment	1	1,500
Replacements for irrigation components	1	750
Cold room (container size)*	2	9,000
Packing shed with grader *	2	54,000
Fork-lift – bought second-hand *	3	8,000
Bins (30) @ $165 *	3	4,950
Air blast sprayer	3	21,000
Pruning equipment replacement	5	876
Cherry picker	5	24,000
Replacements for irrigation components	6	750
Herbicide sprayer	10	1,800
Utility – bought second-hand	10	12,750
Slasher	10	4,500
Pruning equipment replacement	10	854
Replacements for irrigation components	11	750
Spray pump replacement	13	4,875
Tractor (18 HP)	15	22,500
Spray machine pump replacement	15	5,000
Trailer x 2	15	3,600
Pruning equipment replacement	15	854
Workshop and office equipment	15	2,125
Replacements for irrigation components	16	750
Fork-lift*	18	6,800
Bins (30) @ $165*	18	4,950
Picking bags (10) @ $50	18	500
TOTAL CAPITAL COSTS (including land)		**$914,874**

* Not required if fruit are packed using a cooperative pack house

Managing the business: Marketing

The second step in managing the business is to understand the avocado market. A clear idea of marketing provides a base on which production systems can be confidently and profitably planned.

Why marketing is important

Avocados compete in a market that is both increasingly competitive and rapidly changing. This makes it vital that growers are actively in touch with their markets. Here are some of the key issues to consider.

The volume of avocado production in Australia is increasing significantly as new orchards come on line, making the domestic market tighter and more competitive. To maintain a profitable margin, growers need to search actively for new market opportunities in Australia and overseas. They also need to be more active in strongly promoting the fruit to consumers. As few growers have the resources to do this individually, there is increasing need to work together through packing houses, marketing groups or cooperatives to develop greater power in the market chain.

The changing nature of marketing has seen supermarkets begin to dominate the management and distribution of fruit. This domination is moving the focus away from the wholesale markets to more direct buying or brokering arrangements with growers and marketing groups. This will require significant structural and attitude changes for growers in marketing their fruit.

Food safety and quality issues continue to grow in importance to meet modern market needs. Consumers are becoming more demanding with their requirements and are better at communicating these to marketers. Growers need to be in touch with these market needs and gear their production and marketing system to deliver a product that meets those standards.

The 'inside' of marketing

The first thing to do is to develop a clear idea of what marketing entails. This provides a good base on which to plan how the product will be produced.

Marketing *is not* selling. Marketing *is not* waving your product goodbye at the farm gate in the belief that someone else will look after your best interests.

Marketing *is* profitably meeting consumers' needs within the limitations of your resources. Successful marketing implies knowing who and where your consumers are, and what they want. It also implies knowing at what level of returns you are making a profit. Sadly, Australian horticulture provides many examples of growers who have no idea of how or if their product is meeting consumers' needs. In addition, the financial performance of many horticultural businesses indicates that there is also a lack of understanding about how cost of production is linked to marketing success. Many growers blame the 'marketing system' for this state of affairs, but this is virtually admitting they are somehow outside the marketing system. Nothing could be further from the truth.

Here are some ideas as to how an avocado grower can get an 'inside' into marketing.

Think as if you were a consumer—put yourself in the consumer's shoes.

What does an avocado consumer look for? Is it price? Quality? Size? Variety? Or some combination of these factors? If new growers cannot reasonably guess the answer to this question, how can they set targets for production? For example, one decision is how hard to grade out blemished fruit. Grading too hard means fewer trays of very high quality; grading too lightly means more trays of lower quality. At what point are market returns the best? How can a grower make these management decisions without information about what consumers want and how much they are prepared to pay?

There are two important sources of knowledge and information on what the market wants:

- **Market research studies** are conducted by industry and research organisations and published in special reports. Grower organisations, Queensland Fruit & Vegetable Growers, and Horticulture Australia Ltd are sources of this information.
- **Marketers who are in close contact with buyers and consumers.** For the domestic market, specialist avocado wholesalers in the major metropolitan markets are an invaluable source of detailed market knowledge. Market authorities in each of the major markets can provide advice on specialist wholesalers. Grower cooperatives or marketing groups are also good sources of information. For the export market, fruit and vegetable exporters are an equivalent source of market knowledge.

In general, consumers want avocados that are:

- near ripe;
- reasonably free from blemishes;
- of typical shape and size for the specific variety;
- of good internal quality without discolouration or bruising;
- of smooth flesh texture without lumps or stringy, hard or rubbery areas;
- of good colour and flavour.

Know the marketing chain for your fruit

Knowing the marketing chain for your fruit means identifying all the steps and all the people that link your fruit at the farm gate to particular groups of consumers. One chain might include a transport company, an unload-

ing company, a wholesale merchant, a supermarket buyer, a grocery section manager and consumers from a particular region of a city. Knowing how the chain works is important because you choose some of its players, and each of the players in the chain make decisions about your product that collectively influence its marketing performance.

Visit the markets in which your fruit is sold

There is no substitute for seeing how your fruit is performing in its markets. But just looking at the fruit is not enough. You need to monitor the physical and financial performance of the fruit, and assess the performance of your marketing people. Remember, they are working for you, but will happily ignore this if allowed.

Harvest wisely

Delays between harvest and consumption can lower fruit quality. Delays can occur when the supply of fruit at the wholesale level exceeds the rate at which it is being sold. Good communication with your wholesaler will help you to manage your harvest in line with market needs.

Actively seek market information

Apart from visiting the market, actively seek information about each consignment of fruit. Ask your wholesaler or marketer for a report. Growers do not necessarily get feedback unless they ask for it and set up a system for feedback by facsimile or e-mail. Out-turn inspections by independent assessors are another useful way to get information about your product.

Join a marketing collective

Small growers on their own have little clout in the market and also miss out on sharing information with other growers. If you're considering marketing on your own so you can closely guard information you don't want others to have, think again. The greatest risk is that while you're busily guarding this information, the rest of the industry will pass you by because no one will want to share their information with you! Joining a group of like-minded growers for the purpose of marketing is a very positive step towards overcoming the dual problem of lack of marketing clout and lack of information. The avocado industry has many excellent examples of marketing collectives where growers take responsibility for their marketing outcomes.

If you belong to a small group without the resources for a full-time marketing manager, consider using a professional marketing coordinator. Marketing coordinators maintain close contact with all of the markets and direct the product to each market based on their intimate knowledge of demand and price dynamics. A coordinator may also undertake market development and promotion on behalf of the group.

Support market research and promotion

In a highly competitive market, you cannot depend on the product selling itself, no matter how good it is. Support any on-going research proposed by the industry, as it will greatly benefit future marketing opportunities. Avocados, for example, have been identified as having particular health

benefits such as providing a valuable dietary source of folate and reducing the risk of heart disease. Current research is investigating its positive health benefits in combating breast cancer.

In a similar vein, support promotional activities implemented by the industry. Although the avocado has a unique flavour, for most people it is an acquired taste, which needs to be developed and encouraged. The avocado industry has ongoing marketing strategies in place through the Australian Avocado Growers' Federation and Horticulture Australia Ltd to increase domestic market consumption. These activities will increase sales and potential returns. Promotion also helps to build consumer confidence in the product by improving their knowledge of the availability, storage and use of the fruit.

Because of the increasing dominance of supermarkets in fruit and vegetable retailing, a special opportunity exists for marketing groups to work cooperatively with supermarket chains. Growers could contribute cash and product for promotion and, in return, obtain information on consumer preferences and an expanded consumption of their product. They also have the opportunity to develop a special long-term relationship directly with their retailers. This is not a strategy aimed at improving *prices*, it is aimed at improving *returns* through continued customer satisfaction. Growers or grower groups who wish to supply major retailers direct will need to have an on-farm HACCP-based (Hazard Analysis and Critical Control Point) quality management system to ensure food safety.

Notes on the avocado market

Domestic market

The Australian avocado industry produces about 30 000 tonnes of fruit per year, with most marketed on the domestic market. Peak production is in winter, when wholesale market prices are commonly around $10 to $12 per single layer tray. Production is lowest during January–February and wholesale market prices may reach $24 per single layer tray. During this time, some fruit is sourced from New Zealand.

Quarantine barriers restrict competition from imports at this stage to fruit from New Zealand. The New Zealand crop conflicts mainly with the southern Australian harvest, with the end of the New Zealand Hass season coinciding with the start of the Australian harvest of greenskin avocado varieties around mid-February. Increasing production from southern Australia will increase future competition during this period.

Most Australian avocados are marketed fresh and only a small quantity is processed. Some fresh product is sold to the food service industry for use in prepared salads and dips.

The highest per capita consumption of avocados is generally in the main production states of Queensland, New South Wales and Western Australia (Table 2). Although domestic consumption is increasing, there is a need for continuing growth in the domestic market to cover the increases in production expected from new plantings.

***Table 2**. Avocado consumption in Australia*

State	Production (% of total)	Consumption (% of total)	Population (% of total)	Consumption per capita (kg)
Queensland	54.5	20	18	1.36
New South Wales	25.6	43	36	1.39
Western Australia	7.3	8	9	1.03
Victoria	9.2	20	25	0.88
South Australia	3.4	7	9	0.90
Tasmania	0	2	3	0.77

Source: ABS 1996, AC Neilsen Homescan 1998, AHC analysis

Consumers regard avocados as a special occasion purchase. Research commissioned by the Australian Horticultural Corporation in 1998 indicated that 46% of all households consumed avocados at least once, but only 18% of households bought avocados more than six times in a year. Ongoing advertising and marketing programs funded by growers through their peak industry organisations are aimed at increasing consumer purchase levels and broadening usage patterns. Recruiting new consumers to the product and ensuring they become repeat purchasers means they must experience continued satisfaction with the product (consistent quality) and perceive it to be value for money. One of the main factors reducing repeat purchases is the high proportion of bruised and anthracnose-infected fruit on the market.

Export markets

Less than 1% of Australia's total avocado production is exported (1997–98 figures). The Australian industry is therefore a small player in the world avocado market.

At present, there are relatively few entry restrictions for export of fruit into markets such as Singapore and Hong Kong. A phytosanitary certificate must accompany the shipment. Other markets have more complex import requirements and some are currently not accessible to Australian avocados. For example, Australian fruit is currently not permitted into Japan and the USA, as disinfestation treatments for fruit fly have not yet been approved.

However, in the future, export markets will grow in importance. To succeed, individual growers must be prepared to adopt an *export marketing mentality*. This means accepting the following principles:

- Strict quality standards will apply.
- Growers will have to work collectively with other growers if they are to extract the potential rewards from exporting. Building good relationships is the key to developing markets. There is a need to go to the market and find out what it wants and how much the consumers are prepared to pay. While individual growers can achieve this, they would probably be unable to supply enough product to build any meaningful relationship with exporters, importers and retailers. Groups of growers can command more product, and therefore can command more attention from marketers. They can also build brands that identify their product for the benefit of consumers.
- Export markets require long lines of consistent supply of quality fruit throughout the particular market window.
- Growers will accept the responsibility for the performance of their product all the way to the consumer in another country. Good relationships with people along the marketing chain are built on reliability, meaning

that each party in the relationship reliably satisfies the other, that is a 'win-win' situation is developed. The only way growers can extract their potential financial share out of exporting is to actively become part of this network of relationships. This is a somewhat non-traditional view of export marketing in Australian horticulture.

- Groups of growers can join networks of existing relationships, or they can initiate new networks. Existing networks may be accessed through exporters and importers known to be open to active grower involvement. Developing new networks demands more effort, but has the advantage of being 'untainted' by the effects of previous performance by all parties.
- Growers should not expect export markets to provide higher returns than the domestic market.
- Growers may have to travel overseas, partially at their own cost. It is not possible for growers to build reliable relationships in export markets without visiting them regularly. This may even mean getting on a plane at short notice to investigate a particularly serious problem with the product.
- Growers may have to try new and uncertain technologies, such as modified atmosphere packaging, and no one will guarantee they will work.

Managing the business: Quality management

Once you have established what the market wants, the next step is to gear the production and marketing system to deliver a product with those specifications. The only way of ensuring this is to have a quality management system at the farm level.

An understanding of the principles of quality management will help producers decide what type of quality system they need to implement to meet customer requirements. This section outlines the principles of quality management and describes the systems that growers can use.

What is quality management?

Quality has been described as the fitness of a product for its purpose. It implies a predictable degree of uniformity and dependability. But quality goes beyond just the product; it also includes services such as packing true-to-label and delivering on time. In short, quality includes all those points that satisfy your customers.

Quality management is the way you run your business to satisfy customers. This means that growers are constantly engaged in quality management, perhaps even without being aware of it.

In the past, the suitability of the product for its intended market was determined by what is called 'end point inspection'—inspection at the market level. This system has several important flaws:

- It is expensive to reject product at this late point in the chain.
- It is difficult to predict product performance during the rest of the marketing process when its past history is unknown.
- It is often driven more by tradition than by real market needs.

The objective of modern quality management is to build quality right through the production and marketing process so that there is little or no need for rejections late in the chain. This system also provides customers with documented evidence that the product they are buying will meet their needs.

As such, quality management is a marketing tool to achieve repeat sales, as well as a productivity improvement tool to identify problem areas, prevent mistakes and reduce wastage. It also helps growers access markets with quarantine and other barriers to normal entry and promotes greater trust and cooperation throughout the market chain.

There are four principles of quality management:

- The customer defines quality, not the grower.
- Quality management has to be planned, organised and managed, it does not happen by itself.
- Problems are identified at the earliest possible point, not at the end point.
- Everyone in the business, including hired labour, is responsible for quality management; it is not just the responsibility of management.

To implement an effective quality management system, growers will need commitment, good planning, staff involvement and well-organised documents (including records and product specifications).

The push for quality management

The three major supermarket chains in Australia are now demanding that all their suppliers have some level of quality management to assure safety and quality of products. This is in response to consumers wanting fruit and vegetables that are consistently attractive, nutritious, tasty and safe to eat. People are worried about unsafe food because of recent outbreaks of food poisoning from other food products. We cannot be complacent about food safety because fruit and vegetables have been implicated in several food poisoning outbreaks overseas.

What level of quality management is needed?

The three broad levels of quality management practices being requested by customers are:

- Approved Supplier Program (ASP) or Freshcare;
- Hazard Analysis and Critical Control Point (HACCP) Plan;
- HACCP-based quality management system or code.

The level of quality management you need to implement will depend on the marketing arrangements and the potential risk of the product causing a food safety problem.

If your product is supplied directly or indirectly to a supermarket, the minimum level of quality management needed by different businesses in your supply chain is shown in Figure 5.

Some food service businesses, such as fast food outlets, are requesting a HACCP plan or specific quality management practices under an Approved Supplier Program.

Exporters will require some level of quality management, depending on their customers.

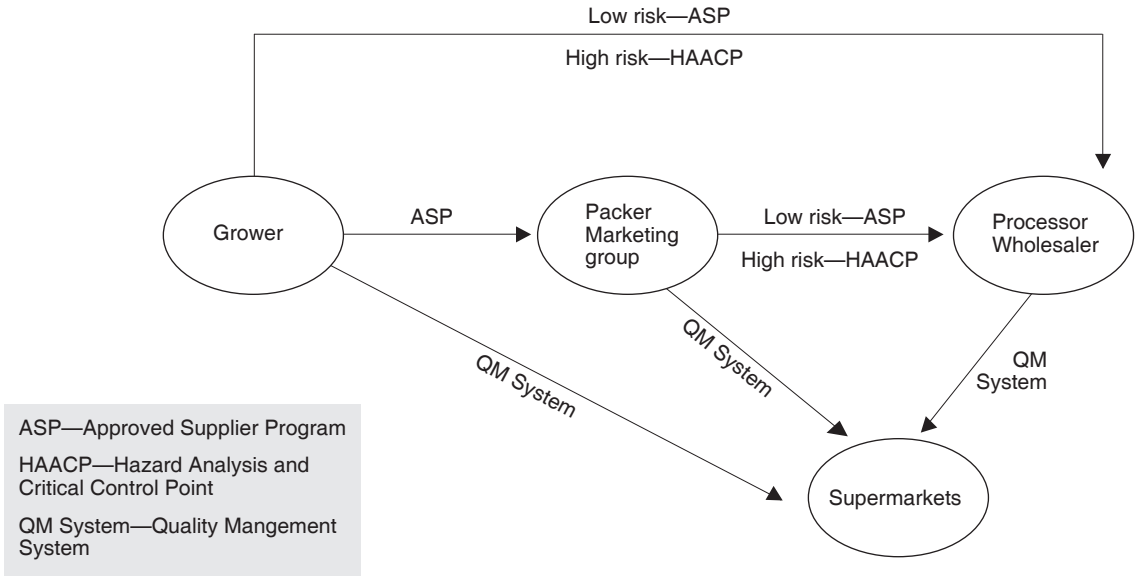


Figure 5. *Minimum levels of quality management required for businesses to supply supermarkets*

The three levels of quality management

Approved Supplier Program

An Approved Supplier Program involves suppliers carrying out agreed practices that will provide assurance to customers that the product is safe to eat and of acceptable quality. Suppliers will need to keep sufficient records to demonstrate that the practices are a part of everyday operations. The customer or someone on behalf of the customer will periodically check that suppliers are carrying out the agreed practices.

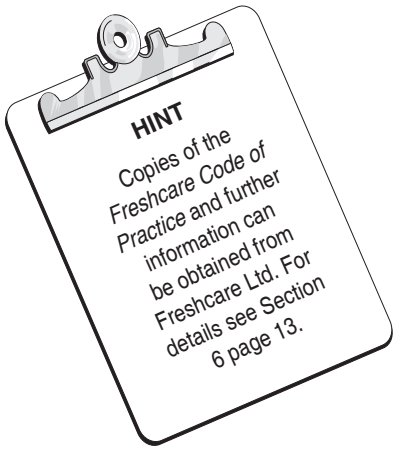
In simple terms, the records for an approved supplier system are about:

- providing evidence that you have taken due care to produce safe food;
- providing the means to trace a product back to the site of its production;
- providing records which can be used to improve fruit quality and farm management.

Direct suppliers to supermarkets need to develop approved supplier arrangements with their grower suppliers. This could include:

- wholesalers or processors who supply direct to a supermarket;
- packers who supply direct to a supermarket;
- marketing groups who supply direct to a supermarket. The marketing operation within the group would need to have a HACCP-based quality management system or code and have approved supplier arrangements with their growers.

Further information about specific practices and documents that may be included in an Approved Supplier Program is in the publication *Developing an Approved Supplier Program for Fresh Produce—a Guide for Customers and Suppliers.*



The fruit and vegetable industry has developed a special on-farm food safety program called Freshcare. Wholesalers, processors, packers and marketing groups may use Freshcare as a minimum requirement for their approved supplier program. Certification to Freshcare is achieved through an independent audit on farm for compliance with the Freshcare Code of Practice.

HACCP plans

HACCP is an internationally recognised method to identify, evaluate and control hazards (things that can go wrong) to food products. HACCP was originally developed to provide assurance that food was safe to eat, but it is now being used to ensure that customer quality requirements are met.

HACCP is being requested of some growers who supply products that are perceived to have a high risk of causing food safety problems or where the next business in the supply chain demands it.

HACCP relies on prevention to control potential problems. Potential hazards are assessed for significance and control measures are established to eliminate, prevent or reduce the hazard to an acceptable level.

Typical food safety hazards include excessive chemical residues, microbes causing sickness, and physical contaminants (glass, sticks) that may lodge in the product.

Some independent auditing companies will certify HACCP plans according to the Codex Alimentarius Commission guidelines.

HACCP-based quality management system or code

The quality management systems or codes incorporating HACCP that are relevant to the horticultural industry are:

- ISO 9002 plus HACCP
- SQF 2000^{CM}, SQF 1000^{CM}
- HACCP 9000
- Supermarket quality management standards.

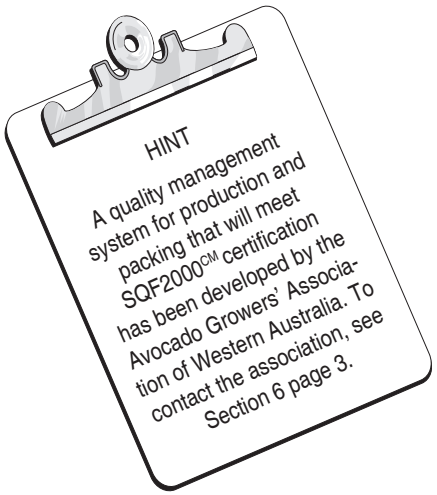
HACCP-based quality management systems or codes are required where growers or pack houses directly supply supermarket chains or where the next business in the supply chain demands this requirement. Check with each supermarket to see what systems or codes they will accept.

For SQF 2000^{CM}, SQF 1000^{CM}, ISO 9002 and HACCP 9000, an accredited independent company conducts audits to certify that the business meets the quality system standard.

For supermarket quality management standards, the supermarket, or an independent company on their behalf, does the auditing.

ISO 9002

ISO 9002 is the international standard for quality management systems and the system on which most others are based. It was developed originally for manufacturing companies and is now used by many industries. It consists of 20 elements covering all aspects of producing products and servicing customers. Supermarkets are requiring their direct suppliers to include HACCP in their ISO 9002 systems.



SQF 2000CM and SQF 1000CM quality codes

The SQF2000CM and SQF 1000CM quality codes were developed by AGWEST Trade and Development specifically for small businesses in the food industry. They are recognised in Australia, some Asian countries, the USA and some European countries. The codes have specific requirements that must be addressed to achieve certification. The SQF2000CM Quality Code includes HACCP and requires a HACCP plan to be developed, validated and verified by a HACCP practitioner. The SQF 1000CM Quality Code is based on HACCP and requires a food safety plan to be prepared from a master industry HACCP plan that has been verified by a HACCP practitioner.

HACCP 9000

HACCP 9000 is a quality management standard incorporating ISO 9002 and HACCP.

Supermarket quality management standards

An example of supermarket quality standards is the Vendor Quality Management Standard developed by Woolworths Australia for their direct suppliers. It is aimed at food safety and quality requirements and is a HACCP-based quality management system.

Managing the business: AVOMAN and AVOINFO software

AVOMAN and AVOINFO are computer software packages developed specifically for Australian avocado growers. They can be a valuable aid in managing the avocado business. AVOMAN is used to record farm information, guide management decisions and monitor production performance. AVOINFO is used to source information on all aspects of avocado production and marketing. This section tells you what you need to know about using these software packages.

The AVOMAN decision support system

Background to AVOMAN

AVOMAN is a software program that integrates extensive record keeping facilities with expert knowledge to provide highly customised agronomic recommendations, reports and information. It is essentially an avocado orchard management tool. It was developed by the Department of Primary Industries, Queensland with assistance from NSW Agriculture and Agriculture Western Australia. These three state government departments, the Australian Avocado Growers' Federation and the Horticultural Research and Development Corporation provided funding for the project.

Features of AVOMAN

AVOMAN applies the results of scientific research and experience to the individual characteristics of each block of trees to provide customised recommendations. These recommendations, combined with comprehensive record keeping and reporting, extensive information files and a unique method of determining the timing of operations, are designed to assist the grower to achieve greater productivity and fruit quality in the orchard. The comprehensive record keeping and reporting facilities can be used for quality management and farm management.

Customised recommendations

Customised recommendations can be obtained for:

- Nitrogen
- Phosphorus
- Potassium
- Liming
- Calcium
- Magnesium
- Boron
- Zinc
- Iron
- Manganese
- Copper
- Root rot control control
- Anthracnose control
- Insect pest control
- Use of plant growth regulators

Data such as the latest leaf and soil analysis of the orchard, soil texture and crop load are automatically taken into account to derive the most appropriate nutritional recommendations.

Product database

The software accesses a product database that contains the details of over 200 fertilisers and registered chemicals (Figure 6). Users can add more products to this database if required. Pesticide registration details within the product database ensure that only registered chemicals are used for an insect or disease recommendation.

Growth cycles

The timing of each recommendation is determined by the growth stage within the annual growth cycle, rather than by the calendar month. The package contains over 30 growth cycles that cover the main varieties and growing regions (Figure 7), and the user can readily fine-tune a cycle to match the appropriate season and district.

Management records

When a recommendation is sought, the user can automatically log it as a future reminder or completed task and include extra details such as labour and machinery costs, weather conditions and the employee responsible (note that recording of employee responsibility is now an essential requirement of spray diary maintenance). Considerable flexibility is offered to the user to choose the method, the interval and the product to satisfy a recommendation. Other data that can be recorded include leaf and soil analysis results, tensiometer readings, irrigation, yield, quality, fruit returns, weather, employee and customer details.

Reports

Nearly all information recorded in AVOMAN can be reproduced or summarised in the form of reports. Over 30 different reports and graphs can be generated from the information recorded.

The user can determine parameters such as the reporting period and the degree of detail to be included.

Some AVOMAN reports and graphs:

- *Spray diaries (to suit Quality Assurance needs)*
- *Water management*
- *Fertiliser use*
- *Weather*
- *Job reminders*
- *Yield, packout and returns*
- *Leaf and soil analysis*
- *Chemical, labour and machinery expenditure*

Information files

Extensive help files not only provide information about using the package but also contain several hundred pages of up-to-date information ranging from deficiency symptoms to canopy management (Figure 8). Direct links are provided from various parts of the program to relevant help files.

User support

User support is offered in several ways. Technical support is available by telephone, facsimile or e-mail from the development team at DPI, Nambour, Queensland. A 'noticeboard' on the AVOMAN web site is kept up-to-date with important information concerning the software as well as industry events. A newsletter is produced as required. Hands-on software training is held from time to time and Regional Productivity Groups hold farm walks.

One software update has been issued since the commercial release of the product and more will be issued if industry support continues. A comprehensive and well-illustrated user's guide accompanies the software.

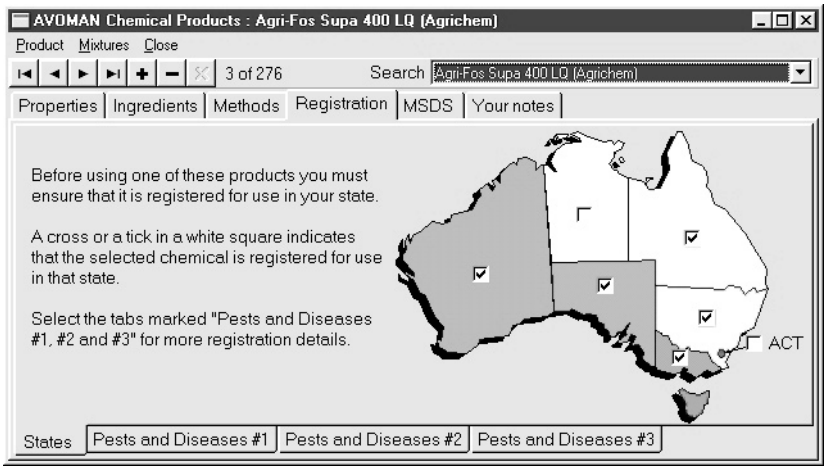


Figure 6. *A screen from the AVOMAN product database*

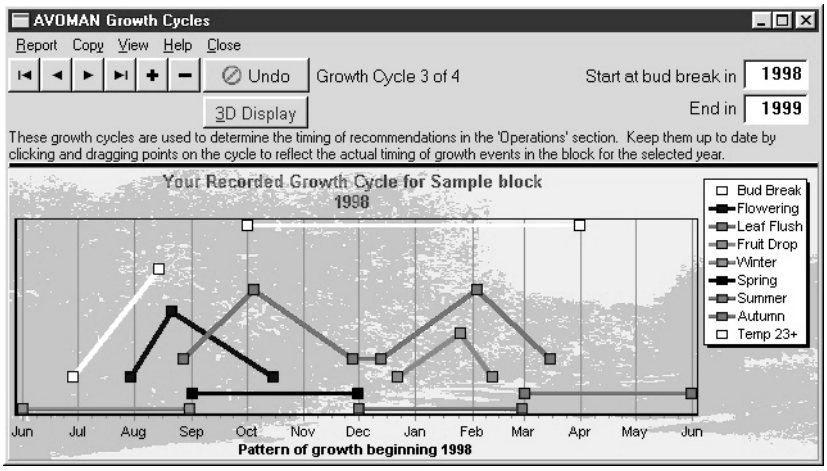


Figure 7. *An AVOMAN growth cycle*

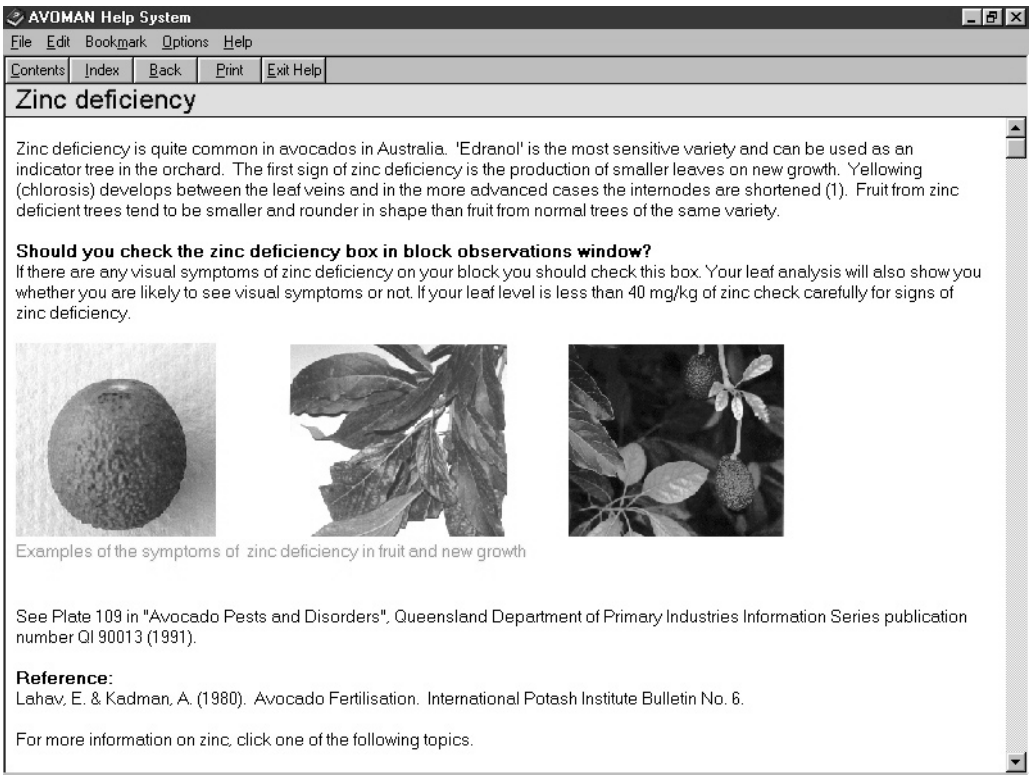


Figure 8. *AVOMAN help file on zinc deficiency*

The future of the software

A survey conducted in 2000 found that AVOMAN users represented over 40% of national avocado production. They expressed a strong desire for AVOMAN to be kept up-to-date and technical support provided. Users reported financial benefits from using the software ranging from $250 a year to over $50 000 a year. The industry and the development team want to ensure the program remains relevant to the needs of producers and that technical support continues to be available. This will be achieved by incorporating the results of new production technology and information as it comes to hand, developing new reports to cater for growers' quality management and business needs, and ensuring resources are available to provide technical support.

The AVOINFO information system

Background to AVOINFO

AVOINFO is a computerised avocado reference database containing the bibliographic details for over 4000 published articles from around the world. Copyright release has been obtained for more than half the articles, allowing inclusion of the abstract or full article. Some pictures, graphs and tables are also included. The references span more than 70 years. Where key articles have been published in foreign languages, English translations are also included. Growers, scientists, extension staff and research administrators are using the program.

The aim of AVOINFO is to provide easy and intuitive access to an extensive library of published avocado information from the comfort and convenience of the farm or office.

Using AVOINFO

AVOINFO is equipped with a powerful search facility. This allows the user to search for information based on one or more criteria at a time. The criteria are key words, word(s) in the abstract, title, author or source. Up to two items can be used within each criteria and these can be linked by an 'and' or 'or' clause (Figure 9). The search then displays bibliographical details of references found (Figure 10). When abstracts of the references are available, they may be displayed for reading or printing (Figure 11).

The future of AVOINFO

Several hundred copies of the AVOINFO software have been sold in Australia and overseas. The Australian avocado industry and the development team want to ensure the program is kept up-to-date.

AVOMAN web site:
www.dpi.qld.gov.au/avoman

Contact the AVOMAN coordinator:
Simon Newett
DPI, Queensland Horticulture Institute,
PO Box 5083 SCMC, Nambour, Qld 4560
Ph: (07) 5441 2211; Fax: (07) 5441 2235
E-mail: avoman@dpi.qld.gov.au

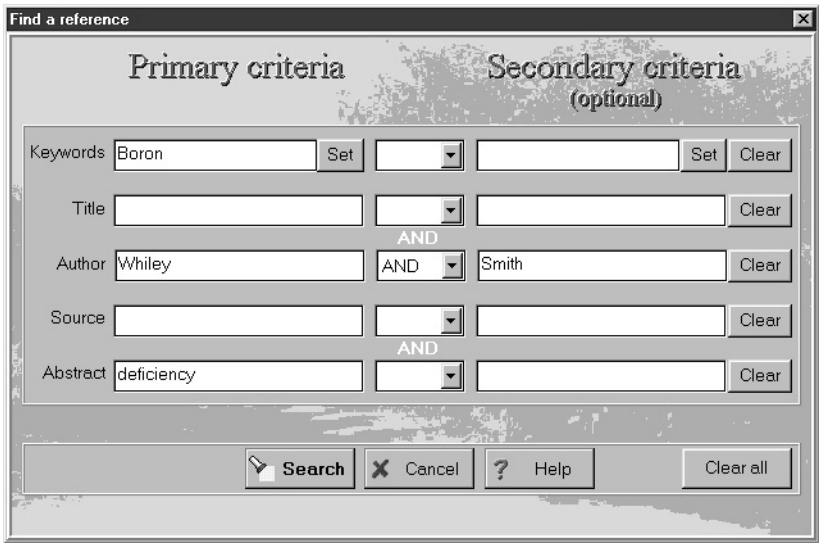


Figure 9. *The search screen in AVOINFO showing criteria entered for a typical search*

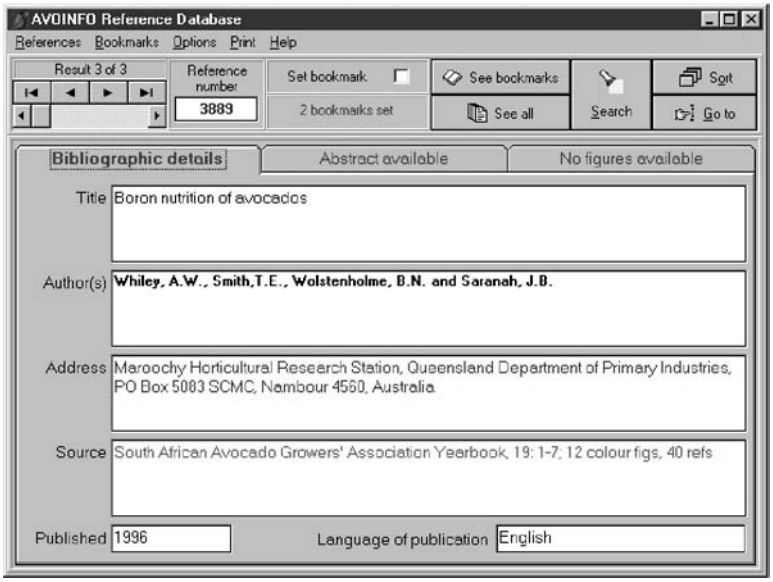


Figure 10. *The bibliographic details of one of the references found in the search from Figure 9*

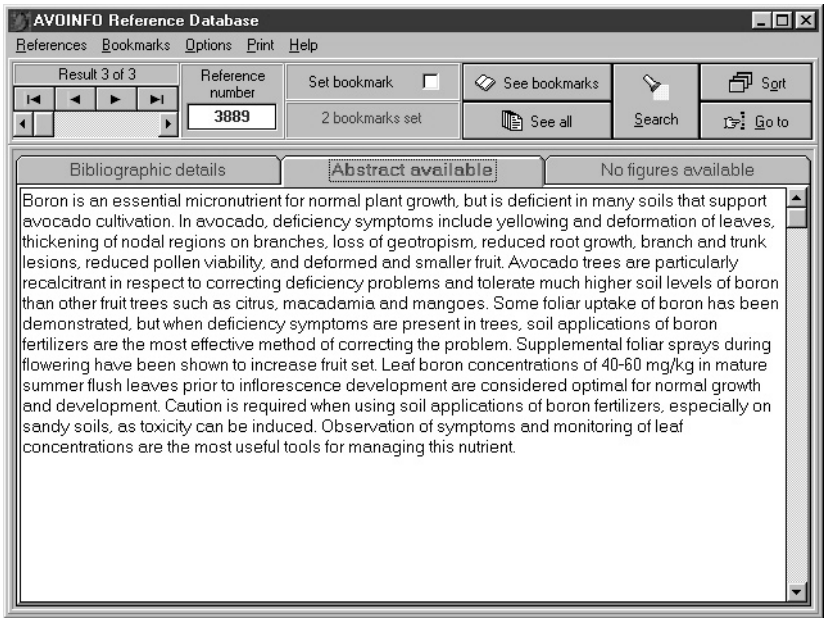


Figure 11. *The abstract for the reference shown in Figure 10*

Managing crop production: Understanding the avocado tree

The aim of avocado growing is to consistently produce a large crop of high quality fruit. To achieve this, it is essential to have a good basic knowledge of what governs fruit production and quality.

Avocado races

Although there is only one species of avocado, three horticultural races are recognised:

- **The Mexican race** is native to the highlands of Mexico and is the most cold-tolerant of the three. A characteristic of the race is the aniseed smell of the leaves when crushed (for example, Fuerte variety). No pure commercial varieties of the Mexican race are grown in Australia, but Mexican race genes are present in several important hybrid varieties.
- **The Guatemalan race** is native to the highlands of Central America and is less cold-tolerant than the Mexican race. Several pure Guatemalan commercial varieties exist and Guatemalan race genes are also present in several hybrid varieties.
- **The West Indian race** is native to the lowlands of Central America and is the most cold-sensitive of the three races. Many pure varieties are found in tropical regions but none are grown commercially in the Australian industry.

The races of the main commercial varieties are shown in Table 3.

Table 3. *Races of the main avocado varieties*

Guatemalan	Predominantly Guatemalan	Mexican–Guatemalan hybrids	Predominantly Mexican
Anaheim	Edranol	Bacon	Fuerte
Nabal	Gwen	Ryan	Shepard
Reed	Hass		Rincon
	Hazzard		Zutano
	Pinkerton		
	Sharwil		
	Wurtz		

Vegetative growth

The avocado is a large, evergreen tree, which flowers in the spring from the tips of the previous summer's growth (terminal flowering). Trees can grow to 18 to 20 m high. The leaves are large, generally dark green, simple, entire, multiform in shape and usually between 100 mm to 400 mm long. They cloak the tree in a fairly dense canopy.

Bearing avocado trees in subtropical Australia generally have two major vegetative growth flushes in a full growth season. Each flush is followed by a period of enhanced root growth. The first vegetative flush begins in spring towards the end of flowering while the second flush is over summer. In the cooler regions of southern Australia, shoot growth is generally confined to one extended period from late spring through summer.

Growth cycles
This section page 43

The vegetative growth of most of the commonly grown varieties can withstand temperatures down to –4°C for short periods without damage. The most tolerant are Mexican or Mexican–Guatemalan hybrids such as Bacon and Fuerte. Vegetative growth can also tolerate temperatures as high as 40°C for short periods without apparent damage. However, prolonged exposure to high temperatures, particularly with low humidity, results in severe stress and loss of productivity.

Flowering

Flowering consists of two stages: flower initiation and inflorescence development, and the opening of flowers.

Flower initiation and inflorescence development

Flower initiation is poorly understood, but shoots that initiate flowers tend to have these characteristics:

- mature at the end of summer;
- high starch levels;
- exposed to direct sunlight.

In most production areas, floral initiation occurs during a period of inactivity following summer growth. A 6 to 8 week period of cool weather is then required for the development and growth of inflorescences—night temperatures not exceeding 15°C (5 to 10°C preferred) and day temperatures not exceeding 25°C (20°C preferred).

The time between floral initiation and actual flowering can range from 6 to 24 weeks depending on temperature.

Flowering

Flowers are small, pale green, lacking petals and grouped together on inflorescences at the end of the branches. A tree may produce about a million flowers during one flowering period, but generally carries only about 1000 of those through to early fruit formation. Flowers are predominantly insect-pollinated.

Flowering is a major event in the tree's growth cycle, contributing 8% to total tree dry matter production. The floral organs increase the potential water loss surface of the tree by around 90% and are demanding on its carbohydrate and nutrient reserves.

more info
Growth cycles
This section page 43

The timing of flowering varies from August–September on the Atherton Tableland to October–November in south-west Western Australia. Flowering in warmer districts lasts three to four weeks, but can extend to eight to ten weeks in the cooler areas of southern Australia.

Avocados have a unique flowering behaviour. Each flower opens twice over a two-day period, the first day as functionally female (pistil receptive) and the next day as functionally male (pollen shedding). The timing of these stages determines the classification of varieties into either an A or B type flowering pattern (Table 4).

Table 4. *Classification of A and B type flowering patterns*

Flower type	MORNING Day 1	AFTERNOON Day 1	MORNING Day 2	AFTERNOON Day 2
A	Female			Male
B		Female	Male	

The opening and closing of flowers over the two-day cycle is regulated and synchronised by air temperature. Under stable flowering temperatures, at any one time all open flowers on a tree are generally either functionally male or functionally female. However, in practice, periods of rapid change in temperature (which are common in spring) disrupt the synchrony and cause some overlap between male and female stages during the middle part of the day. This overlap enables self-pollination. However, where temperatures are consistently cool, the flowers may open only once for an extended period as functionally male and no pollination occurs.

The flower type classification of the main varieties is shown in Table 5.

Table 5. *Flower types of the main avocado varieties*

Flower type A	Flower type B
Anaheim	Bacon
Gwen	Edranol
Hass	Fuerte
Hazzard	Nabal
Pinkerton	Ryan
Reed	Sharwil
Rincon	Shepard
Wurtz	Zutano

The floral cycle of B type varieties is more sensitive to cooler temperatures than A type varieties. This means increasingly longer periods of male-only flowering, with reduced opportunities for pollination and fruit set. For example, floral cycles of B type varieties are disrupted when temperatures during flowering fall below 20°C (day) and 15°C (night). Type A varieties can generally tolerate slightly lower day and night temperatures during flowering without disrupting the floral cycle.

Technically speaking, when B type varieties are grown in areas where temperatures during flowering are consistently below 20°C (day) and 15°C (night), a mixed planting of A and B type varieties within the orchard block may be beneficial in improving pollination. For example, in some years Shepard and Sharwil benefit from cross-pollination. However, it can be difficult to find a pollen source variety that both flowers at the same time as the main variety, and has some commercial value.

SUMMARY

There are three important prerequisites for successful fruit set:

- *some overlap between the male and female flower stages;*
- *sufficient bee or other insect activity to achieve effective pollination;*
- *temperatures above 10°C at flowering and for the ensuing three days.*

When this and the extra difficulties of managing mixed blocks of trees are considered, there may not be sufficient **commercial** benefit to warrant the practice.

In the cooler production areas of southern Australia, mixed plantings may be of benefit in improving cross-pollination for all varieties. However, whether this is again of sufficient **commercial** benefit is still undetermined.

Even when male and female flowers overlap, night temperatures below 10°C within three days of pollination may affect pollination, particularly for temperature-sensitive B type varieties such as Shepard, Fuerte and Sharwil. Common outcomes are poor fruit set and/or the production of cocktail fruit (cukes).

Fruit growth

Avocado fruit has a single large seed surrounded by a thick flesh covered by a skin of varying thickness. Fruit are commonly pear or oval-shaped and can vary in size from 7 to 20 cm long and from less than 300 g to over 3 kg. The skin colour varies from yellow-green through many shades of green to crimson, maroon, brown, purple and almost black. The pulp oil content varies from about 3% to over 30%.

more info
Growth cycles
This section page 43

Immediately following fruit set, there is a drop of poorly pollinated fruit along with a high proportion of apparently normal fruit. This fruit drop coincides with the beginning of the spring flush, when fruit and shoot growth are competing for limited tree resources already depleted by flowering. A second fruit drop usually occurs during early summer. The extent of this drop is related to the tree's crop and is a natural adjustment of the fruit load. Careful fertilising and irrigation practices, together with maintenance of a healthy root system, are essential to manage fruit retention along with the vegetative growth flush.

Crop load is known to affect fruit size, with heavy crops producing smaller fruit. Fruit development is also highly competitive with root and shoot growth and exerts high demands on the tree's water, mineral nutrient and carbohydrate resources. The commercial practice of extending 'on-tree storage' of fruit after maturity may lead to the development of strong biennial bearing patterns.

During fruit development, temperature can significantly affect fruit shape, with fruit produced in cooler environments being more elongated. Pear-shaped fruit lengthen at the stalk end and develop a longer neck while round fruit become more oval.

Avocado is one of the few fruits that do not ripen on the tree when mature. Water loss from fruit after harvesting appears to be the primary stimulus for ripening. Excess soil moisture may also affect ripening behaviour. Prolonged heavy rain over two weeks or so when fruit have reached maturity can trigger partial uneven ripening while fruit are still attached to the tree. This is thought to be due to root loss, which leads to water stress within the tree (and fruit).

Root growth

Root growth is primarily determined by the availability of resources from the tree and occurs each time shoot growth ceases. Roots also grow at lower temperatures than shoots, hence there is an extended period of growth through autumn and winter.

Avocados have a relatively shallow root system, which is highly susceptible to Phytophthora root rot. The roots have few root hairs and the trees are relatively inefficient in water uptake. Internal tree water balance is therefore easily upset.

Consequently, maintenance of soil moisture is vital. Critical demand periods are during flowering and fruit set, fruit drop, and fruit growth and maturation. However, the avocado is also very sensitive to excessive moisture for two reasons. Waterlogging of the root system for more than 48 hours causes rapid root death and may kill the tree. Where the fungus *Phytophthora cinnamomi* is present, excessive soil moisture encourages rapid development of root rot disease, and in combination with flooding, rapid death of the tree occurs.

Typical annual growth cycles

The cycles of vegetative growth, flowering and fruit growth, and root growth vary with location. Figure 12 shows this variation across three sites in Australia.

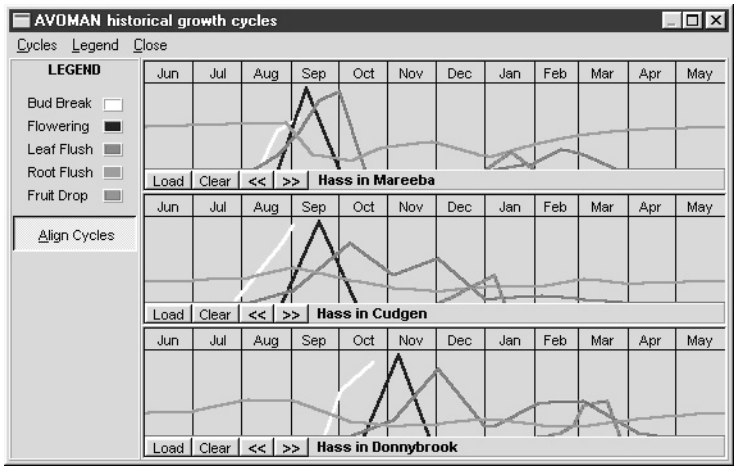


***Figure 12**. Growth cycles for three sites illustrating the different timing of events across Australia.*
From top: Mareeba in North Queensland;
Cudgen in northern New South Wales;
Donnybrook in south-west Western Australia
(figure courtesy AVOMAN software)

Management of bearing avocado trees is a complex process. Leaf, root and flower/fruit growth are dependent on each other, but they also compete for the tree's limited reserves of carbohydrates, nutrients and water. If this competition is not properly managed and the vegetative/reproductive growth gets out of balance, fruit yield and quality is ultimately reduced.

To manage trees better, it is important to understand the growth cycle and the way it is influenced by changes in weather, crop load and orchard operations such as nutrition and pruning. The best way to do this is to record the growth cycle for each variety on your farm. The AVOMAN software provides an excellent growth cycle recording system. Once this knowledge is consolidated, management practices such as nutrition, irrigation, pruning and root rot management can then be modified and programmed to achieve greater productivity.

Managing crop production: Selecting varieties and rootstocks

Although there is a relatively limited range of commercial varieties, it is important that you select those that the market wants and those that suit your location. As rootstocks can have a significant effect on tree performance and fruit quality, rootstock selection is also important, particularly as this cannot be changed once trees are planted. This section will help you understand the different varieties and rootstocks and their advantages and disadvantages.

What makes a good variety?

A good avocado variety needs to satisfy two important requirements:

- market performance;
- production performance.

Market performance

Market performance infers that a variety is acceptable to the packer, retailer and consumer. It includes the retail customer, the food service industry and processors. To perform well at the market level, a variety needs to adequately meet four important criteria:

- good eating quality involving smooth flesh and rich flavour;
- good flesh recovery (small seed);
- good ability to endure current packing and transportation practices and arrive at its destination in good condition;
- good shelf life, with the ability to fit in with current postharvest management standards including holding temperatures and ripening techniques.

Production performance

To produce well, a variety essentially needs to suit the climate in which it is being grown. It needs to adequately meet five important criteria:

- high yielding capacity;
- regular bearing or only slightly alternate bearing;
- good yielding capacity early in the life of the tree (precocious), preferably achieving commercial crops in the third year after planting;
- not prone to excessive vegetative vigour;
- some natural resistance to pests and diseases.

Profiles of the main varieties

To help with selection of varieties, this section analyses eight established varieties for their production and market performance. Main harvest times and the cropping reliability in the main Australian production areas are also shown. The eight varieties represent the main varieties currently available from nurseries, that are still being planted or their fruit is on the market. Notes on newer experimental varieties not yet fully proven follow the profiles of the established varieties.

IMPORTAN NOTES ON THE VARIETY PROFILES

The map shown for each variety indicates the production areas in Australia where it will crop reliably, based on current experience.

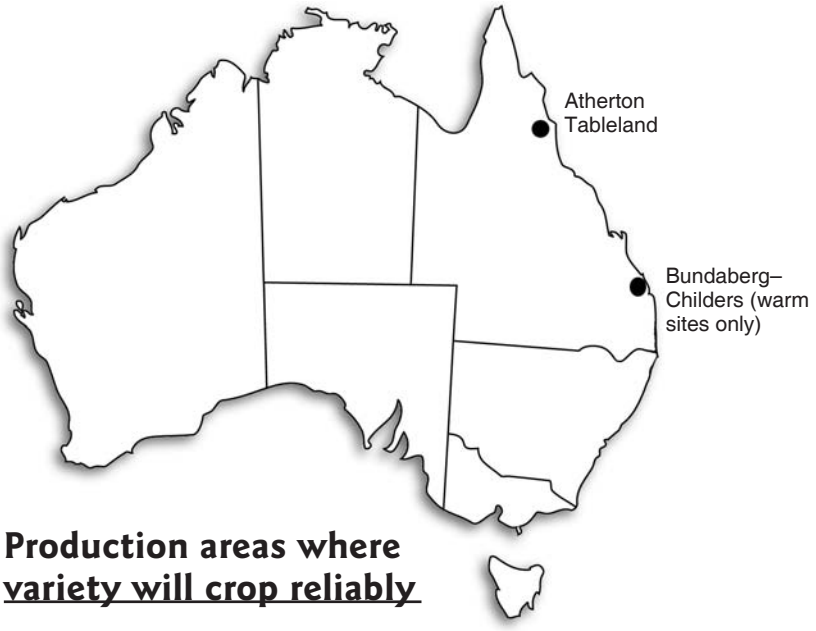
IT IS NOT A RECOMMENDATION THAT THE VARIETY SHOULD BE PLANTED AT THESE LOCATIONS.

This decision needs to be based on market performance and a more thorough assessment of production issues.

Under 'Production Issues', the variety profiles do not include information on the relative susceptibility of varieties to fruitspotting bug or anthracnose disease.

All varieties are considered susceptible, the only differences being that fruitspotting bug damage on thin-skinned varieties is more noticeable, and anthracnose damage on some varieties is more likely to be seen in the field.

Shepard



Production areas where variety will crop reliably

Market performance

- Early maturing
- First new season variety onto the market, so currently has little competition
- If harvested at the correct stage of maturity, well accepted by market
- If harvested too early, fruit may shrivel while the neck remains firm

Production issues

- Dense canopy provides good protection against sunburn and hail
- Smaller tree makes it easier to manage
- Small fruit and large seed
- Potential for mixed maturity because of its extended flowering habit
- Requires special fertiliser and pest/disease management because of its early and extended flowering habit
- Extremely sensitive to cool temperatures at flowering, which will result in poor fruit set

Main harvest times

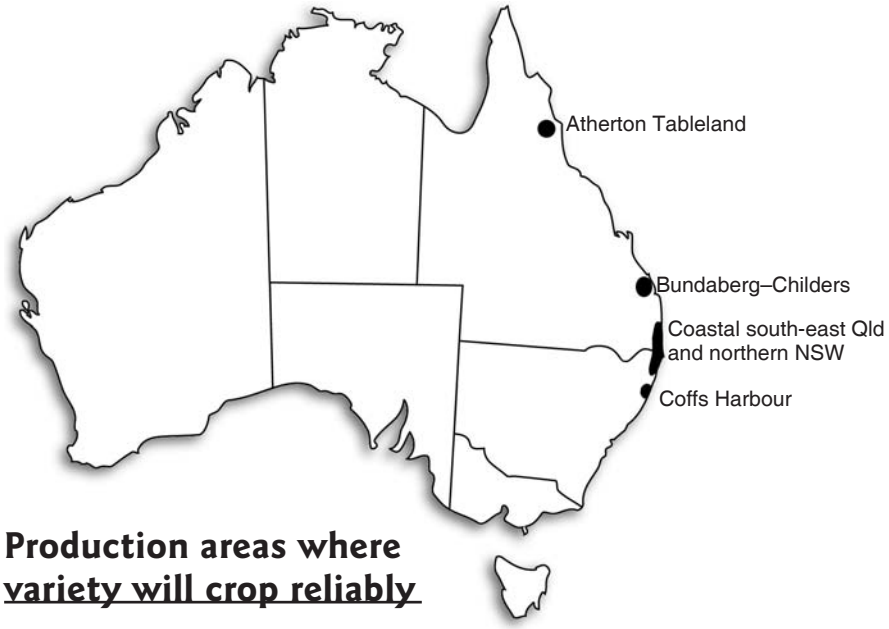
Atherton Tableland

J	F	M	A	M	J	J	A	S	O	N	D

Bundaberg–Childers

J	F	M	A	M	J	J	A	S	O	N	D

Fuerte



Production areas where variety will crop reliably

Market performance

- Early maturing
- Very good eating quality, well regarded and still in demand by some consumers provided the fruit is sound
- Easy for consumers to determine eating quality because its green skin does not mask fruit rots
- Not popular with wholesalers and retailers because of high postharvest losses from anthracnose

Production issues

- One of the most cold-tolerant of varieties for frost damage to leaves
- Sensitive to cool temperatures at flowering, which will result in poor fruit set
- Trees are large and vigorous, requiring more frequent canopy management
- Because of its inherent vigour, careful management of nitrogen fertiliser is required

Main harvest times

Atherton Tableland

J	F	M	A	M	J	J	A	S	O	N	D

Bundaberg–Childers

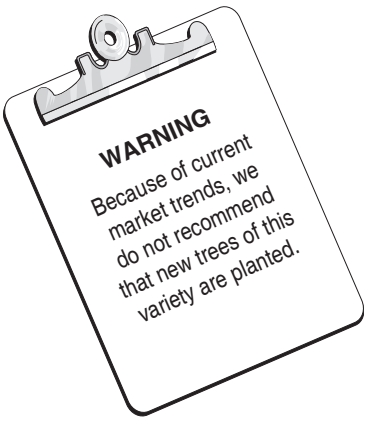
J	F	M	A	M	J	J	A	S	O	N	D

Coastal south-east Qld and northern NSW

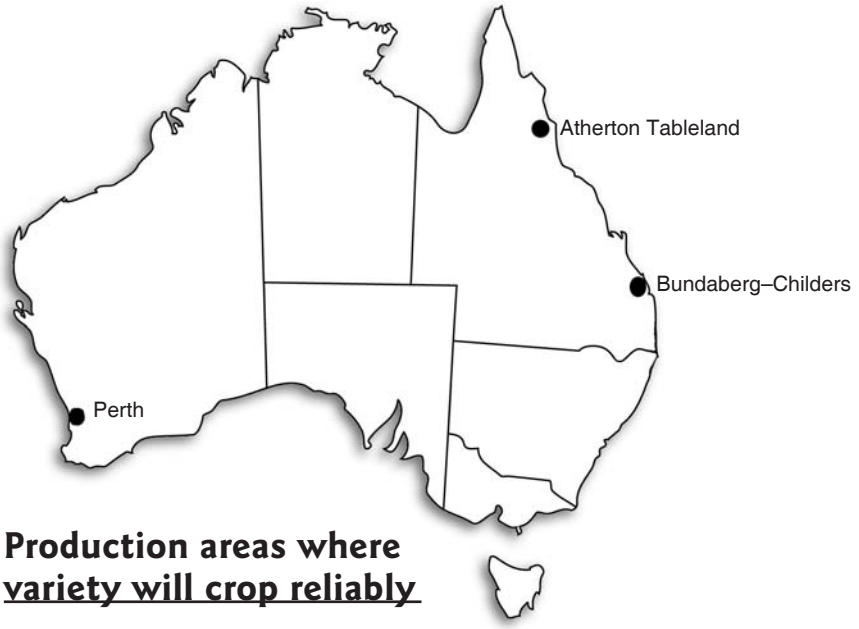
J	F	M	A	M	J	J	A	S	O	N	D

Coffs Harbour

J	F	M	A	M	J	J	A	S	O	N	D



Sharwil



Production areas where variety will crop reliably

Market performance

- Excellent fruit quality. Considered by some consumers to be the best eating of all varieties
- Small seed and good flesh recovery
- Because of large fruit, requires specialised niche marketing

Production issues

- Fruit stores well on trees
- Erratic yielder (in marginal climates)
- Highly susceptible to boron deficiency
- Sensitive to cool temperatures at flowering, which will result in poor fruit set
- Trees large and vigorous, requiring more frequent canopy management
- Weak limb structure. Some limbs may break under heavy fruit loads
- Because of its inherent vigour, requires careful manage-

Main harvest times

Atherton Tableland

J	F	M	A	M	J	J	A	S	O	N	D

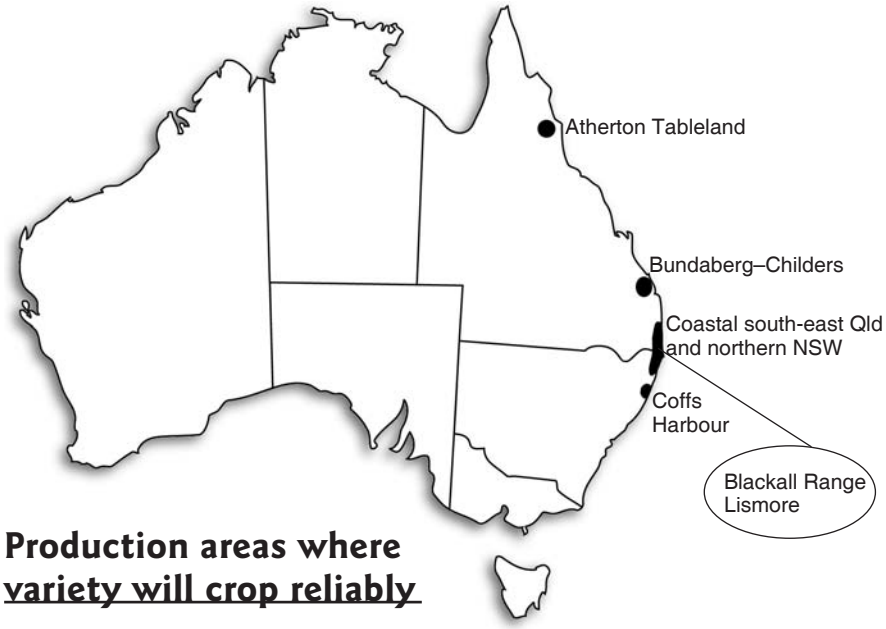
Bundaberg–Childers

J	F	M	A	M	J	J	A	S	O	N	D

Perth

J	F	M	A	M	J	J	A	S	O	N	D

Pinkerton



Production areas where variety will crop reliably

Market performance

- Has long postharvest shelf life
- Good eating quality. Well received by consumers where variety is known
- Not popular or well-known in the market
- May have ripening problems and requires different storage and ripening temperatures to Hass. Best handled by specialist avocado wholesalers

Production issues

- Heavy consistent cropping variety
- Precocious (starts bearing early in the life of the tree)
- Fruit retains size in hot regions and seasons
- Has variable fruit shape and may be difficult to pack; very 'necky' in cooler areas
- In young trees, fruit may have internal quality problems—rubbery flesh, uneven ripening

Main harvest times

Atherton Tableland

J	F	M	A	M	J	J	A	S	O	N	D

Bundaberg–Childers

J	F	M	A	M	J	J	A	S	O	N	D

Coastal south-east Qld and northern NSW

J	F	M	A	M	J	J	A	S	O	N	D

Blackall Range

J	F	M	A	M	J	J	A	S	O	N	D

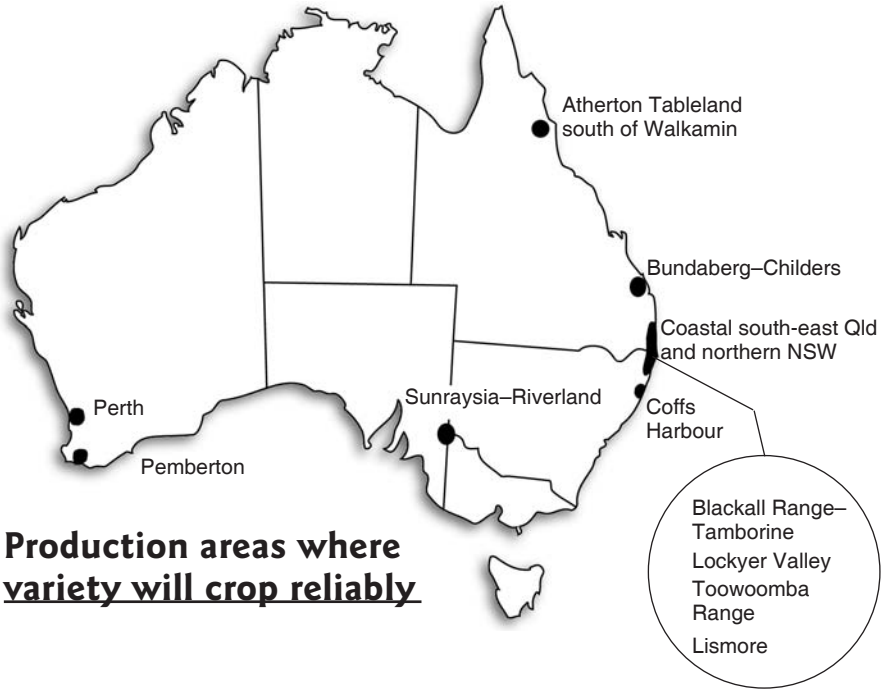
Lismore

J	F	M	A	M	J	J	A	S	O	N	D

Coffs Harbour

J	F	M	A	M	J	J	A	S	O	N	D

Hass



Production areas where variety will crop reliably

Market performance

- Has the highest market acceptance of all varieties by wholesalers and retailers
- Very good eating quality
- Some consumer resistance from the difficulty in determining the internal quality of fruit (disorders such as anthracnose, bruising, etc) because of the black skin

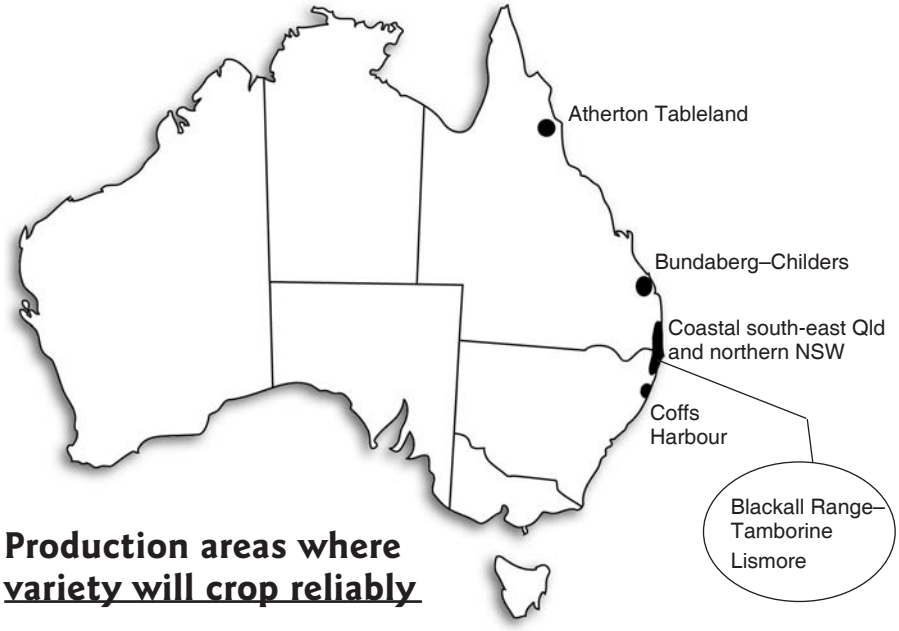
Production issues

- Performs well across a range of environments
- Fairly regular production each year if well managed
- In warm areas, small fruit can be a problem. Stress on trees must be minimised through mulching and good management of nutrition and irrigation

Main harvest times

	J	F	M	A	M	J	J	A	S	O	N	D
Atherton Tableland south of Walkamin					■							
Bundaberg–Childers					■	■	■					
Coastal south-east Qld and northern NSW					■	■	■	■	■			
Blackall Range–Tamborine									■	■	■	
Lockyer Valley								■	■	■		
Toowoomba Range								■	■	■		
Lismore							■	■	■	■	■	
Coffs Harbour								■	■	■	■	
Sunraysia–Riverland	■										■	■
Perth									■	■	■	■
Pemberton	■	■										■

Wurtz



Production areas where variety will crop reliably

Market performance

- Considered by some to have a niche market as an alternative to Hass because of its good size, green skin and pear shape
- Declining in market popularity
- Has a larger seed and lower flesh recovery than other comparable varieties
- Flavour can be unreliable and disappointing, particularly when fruit are hung late
- Competes with Hass when hung late

Production issues

- Small tree; makes it easier to manage
- Precocious (starts bearing early in the life of the tree)
- Has ability to hang late for better prices
- Hanging fruit late may lead to biennial bearing
- Dense leaf canopy makes fruit difficult to protect from anthracnose and insect pests
- Highly susceptible to tea red spider mite and Monolepta beetle

Main harvest times

Atherton Tableland south of Walkamin

J	F	M	A	M	J	J	A	S	O	N	D

Bundaberg–Childers

J	F	M	A	M	J	J	A	S	O	N	D

Coastal south-east Qld and northern NSW

J	F	M	A	M	J	J	A	S	O	N	D

Blackall Range–Tamborine

J	F	M	A	M	J	J	A	S	O	N	D

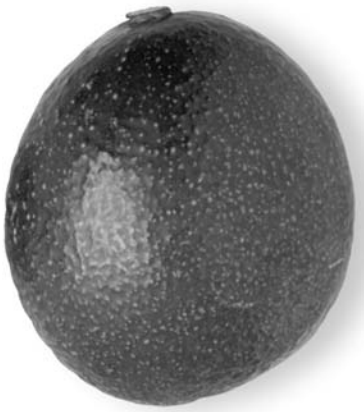
Lismore

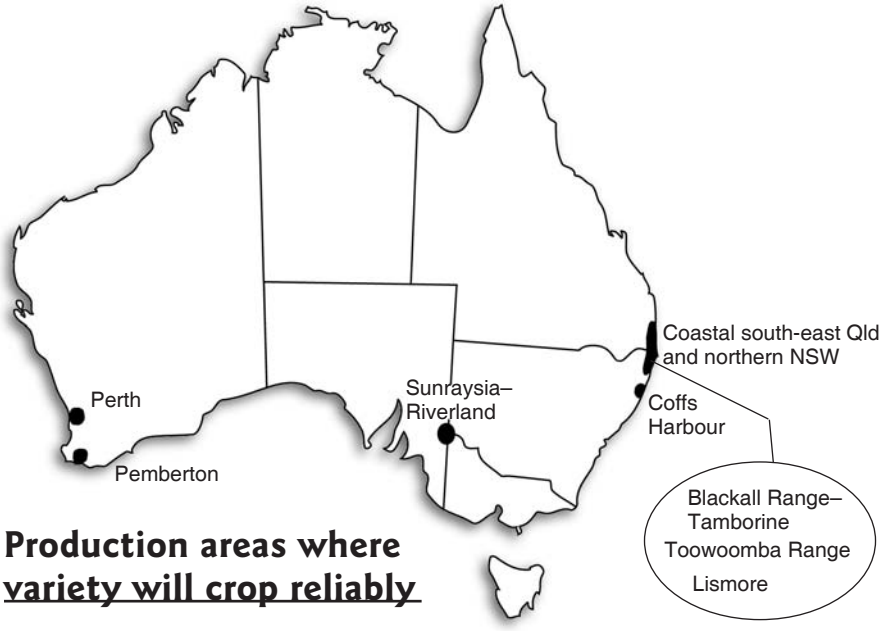
J	F	M	A	M	J	J	A	S	O	N	D

Coffs Harbour

J	F	M	A	M	J	J	A	S	O	N	D

Reed





Production areas where variety will crop reliably

Market performance

- Excellent eating quality—eagerly sought by some consumers
- Late maturity gives market advantage over Hass
- Large fruit and round shape limits market opportunities

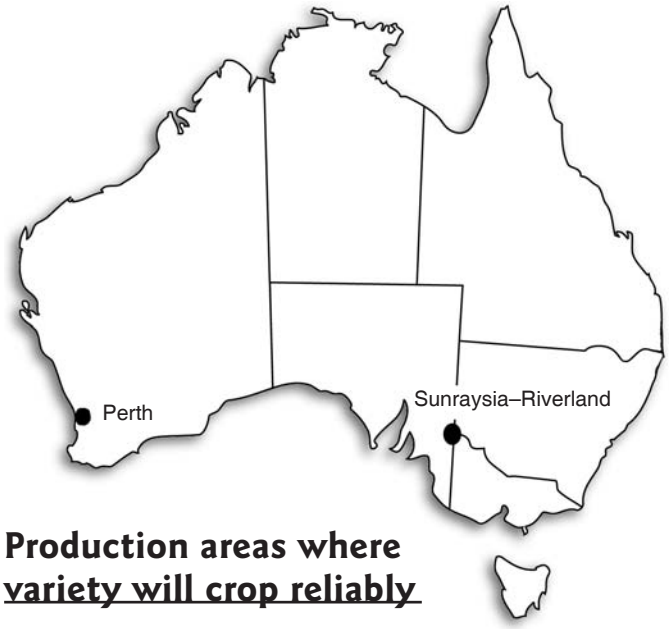
Production issues

- Heavy bearing potential
- Columnar upright growth allows high density planting
- Performs well across a range of environments
- Late maturity (later than Hass) provides potential for better late season prices
- Late maturity may lead to biennial bearing
- Has tendency to drop some fruit at marketable size, prompting an early harvest when fruit are still immature
- Mature fruit on the tree are very susceptible to loss from freeze damage

Main harvest times

	J	F	M	A	M	J	J	A	S	O	N	D
Coastal south-east Qld and northern NSW											■	■
Blackall Range–Tamborine											■	■
Toowoomba Range									■	■	■	■
Lismore											■	■
Coffs Harbour											■	■
Sunraysia–Riverland	■	■										
Perth											■	■
Pemberton	■	■										

Gwen



Production areas where variety will crop reliably

Market performance

- Acceptable fruit quality
- Late maturity (later than Hass) gives market advantage
- Variety not popular or well-known in markets

Production issues

- Semi-dwarf tree makes it easier to manage
- Heavy bearing potential
- Late maturity may cause biennial bearing
- Has tendency to lose all its leaves during flowering

Main harvest times

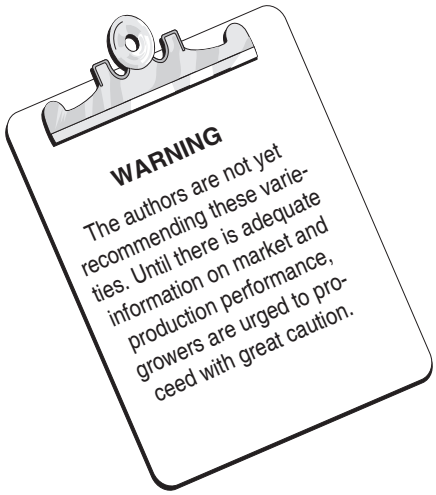
Sunraysia–Riverland

J	F	M	A	M	J	J	A	S	O	N	D

Perth

J	F	M	A	M	J	J	A	S	O	N	D

Promising new varieties



Two new varieties being evaluated are Lamb Hass and Llanos Hass. They are only recently available and knowledge of their production and marketing performance is still very limited. The notes provided are based on early observations from a limited number of production sites.

Lamb Hass

Lamb Hass is a selection from California. Early indications suggest that it differs from Hass in the following ways:

- **Fruit maturity.** Between one and three months **later** than Hass.
- **Precocity and productivity.** Appears to be more precocious and bear heavier crops than Hass. However, because it matures late, it hangs longer on trees and this can lead to the development of a biennial bearing pattern. This has occurred in older trees grown in California.
- **Fruit skin colour:** Although the skin turns black, it does this while still on the tree. This differs from Hass, where blackening of fruit on the tree would generally indicate over-maturity. With Lamb Hass, the fruit turns black as maturity approaches with a speckling of tiny light green spots. As the fruit ripens off the tree, the green spots disappear.
- **Fruit size.** On average, larger than Hass.
- **Fruit shape.** Less rounded than Hass, more angular in the neck area, much 'squarer' shoulders at the stem end, and a flatter base.
- **Taste/texture.** Not as creamy as Hass and flavour is different.
- **Tree shape.** More upright and less spreading than Hass.
- **Postharvest quality.** There are reports from California of fruit breaking down earlier than Hass. It appears more sensitive to chilling injury and this may be linked to the breakdown problem.
- **Other comments.** The industry needs to consider how best to market this variety. Preliminary reports from California strongly suggest that Lamb Hass should be treated as a distinct variety for handling and marketing purposes.

Llanos Hass

Llanos Hass is a recent selection from Western Australia. Early indications suggest that it differs from Hass in the following ways:

- **Fruit maturity.** Between one and two months **earlier** than Hass. The variety goes through its maturity cycle rapidly and has shown early indications that it may be subject to over-maturity if growers try to hold the fruit on the tree for too long.
- **Precocity and productivity.** Appears to be more precocious than Hass, but bears similar crops and to date has not shown a heavy biennial bearing pattern.
- **Fruit skin colour.** Behaves in a very similar way to Hass.
- **Fruit size and shape.** Generally similar to Hass.
- **Taste/texture.** A milder, less nutty flavour than Hass, smooth texture, with no discernible stringiness.
- **Flesh colour.** The green tint near the skin is more pronounced than in Hass and spreads deeper into the yellow flesh.
- **Tree shape.** Marginally more upright and less spreading than Hass.

- **Postharvest quality.** Little is known at this stage.
- **Other comments.** The industry needs to consider how best to market this variety.

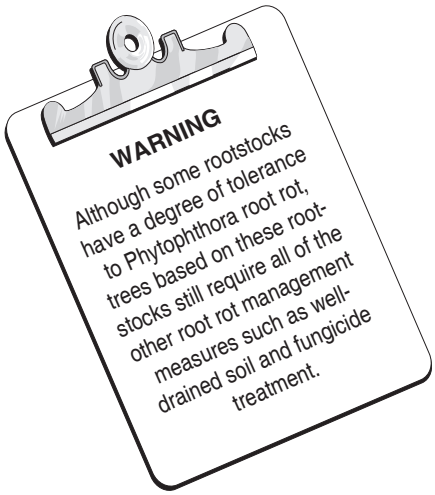
Llanos Hass has a B type flowering behaviour.

Rootstock selection

The importance of rootstock selection

Rootstocks may have a significant effect on the growth of the scion variety as well as its yield and fruit quality. In many ways, rootstock selection is as important as selection of the scion variety. However, in Australia, relatively little attention has been paid to rootstock selection.

The following issues emphasise the importance of rootstock selection.



- The Australian avocado industry is largely based on rootstocks propagated from seed. This introduces extensive genetic variation into the orchard, resulting in trees with widely differing yield and fruit quality. For example, research over six years in a Queensland Hass orchard showed yields from trees on unselected rootstock growing within the same orchard block and receiving the same management varied by up to 400% between the best and worst trees.
- Phytophthora root rot disease is the most serious disease of avocados, requiring an integrated program of preventative and curative measures throughout the life of the orchard. Some rootstocks have a degree of tolerance to the disease, mainly through an ability to rapidly regenerate feeder roots after damage. For example, in subtropical regions, Velvick and Duke 7 appear to have some tolerance. Use of tolerant rootstocks helps to reduce the severity of the disease and produces trees that respond more readily to fungicide treatments.
- Anthracnose is the second most important disease of avocados. It also requires a regular spray program from fruit set to harvest. Recent research has shown that rootstocks play a significant role in the susceptibility of fruit to anthracnose. For example, Hass grafted onto Duke 6 and Duke 7 rootstocks is more susceptible than Hass grafted to Velvick. Avoiding rootstocks that increase fruit susceptibility may help to reduce the severity of the disease and improve fungicide effectiveness.

Understanding rootstock genetics

A wide range of genetic diversity occurs naturally across the three horticultural races of avocado. This can be exploited when selecting material for rootstocks and when choosing individual rootstocks for different environmental and production conditions. A summary of these characteristics is shown in Table 6.

Table 6. *Characteristics of main avocado races*

Race*	Main characteristics
Mexican	• Most tolerant of cold temperatures
	• Most susceptible to saline water or soil conditions
	• Poorest in uptake and translocation of boron and calcium
	• More efficient than Guatemalan in uptake of potassium
	• Produces a smaller tree size than Guatemalan
Guatemalan	• Best in uptake and translocation of boron and calcium
	• Less efficient than Mexican in uptake of potassium
West Indian	• Most tolerant of saline water or soil conditions
	• Most susceptible to cold temperatures
	• Best at handling calcareous soils and high soil pH

* Hybrids are generally intermediate in their characteristics between the two relevant races

Based on their climate and soil types, different countries have favoured specific selections from the races that suit their production conditions. For example, Florida has a semi-tropical climate and calcareous soils. With these conditions, the industry is almost exclusively based on West Indian race material. Israel has also selected West Indian race material as its dominant rootstock type to cope with saline water and calcareous soils. On the other hand, the Californian industry is based on Mexican race rootstocks that best suit the cooler temperatures and high naturally-occurring soil boron levels.

Rootstocks for Australian orchards

Avocado production in Australia covers a diverse range of climates and soil types and it is unlikely that any one selection will have the best performance throughout all growing districts. Based on current knowledge and experience, some broad suggestions can be made (Table 7).

Table 7. *Suggested rootstocks for Australian orchards*

Production region	Suggested rootstocks	Race	Notes
Queensland and northern New South Wales	Velvick	Predominantly Guatemalan (possibly Guatemalan–West Indian hybrid)	• These four rootstocks seem to perform best under the mild temperatures and boron-deficient soils of the region. • Velvick appears to have some tolerance to Phytophthora root rot disease. Nabal and Reed produce good uniform trees with Hass. • Do not use Duke 6 and Duke 7 because of the higher risk of anthracnose disease.
	Plowman	Guatemalan	
	Nabal	Guatemalan	
	Reed	Guatemalan	
South-west Western Australia	Duke 7	Mexican	• Duke 7 appears to have some tolerance to Phytophthora root rot disease. • Reed has shown promise as a rootstock for Hass at Pemberton.
	Zutano	Mexican	
	Mexicola	Mexican	
	Reed	Guatemalan	
Sunraysia–Riverland	Zutano	Mexican	• West Indian rootstocks are being investigated because of their tolerance to salinity. These may provide the best long-term solution but no reliable information on suitable lines yet exists.

Seedling or clonal rootstocks

The Californian and South African industries have been noted for their strong move towards clonally produced rootstocks. These rootstocks have the advantage of genetic uniformity within the orchard. However, in California and South Africa, the move to clonal rootstocks has been largely adopted through the use of rootstocks tolerant to Phytophthora root rot. The major disadvantage of using clonal rootstocks is the higher cost of nursery trees and the greater difficulty in establishing them in the orchard during the first 12 months after planting. In Australia, there has been limited evaluation of trees propagated on clonal rootstocks.

To reduce genetic diversity when using seedling rootstocks, select material from the same maternal source. If several sources are used, keep them separate so that the propagated trees can be planted in separate blocks or rows to facilitate management and the recording of yield performance.

Managing crop production: Tree spacing and canopy management

Maintaining the avocado tree canopy so it is both productive and manageable is one of the most difficult operations in avocado production. It involves choosing an initial spacing that will fit with the tree thinning and pruning system you plan to use.

Understanding the issues

Before looking at the techniques of canopy management, it is important to understand some of the issues that make canopy management in avocados so difficult. Here are the main issues.

- The avocado is a rainforest species, which has evolved to compete for light in that situation. Growth is rapid and, if left unchecked, the tree may reach 15 to 20 m tall and 12 to 15 m in diameter within 15 to 20 years. Under Australian conditions, trees of these dimensions are uneconomical to manage because of the extra costs of spraying and harvesting large trees. Good spray penetration of the canopy and coverage of fruit is more difficult to obtain and they also pose a higher risk of injury to pickers.
- The combination of terminal flowering and the long cropping cycle in the avocado present a unique problem for canopy management. As fruit form on the perimeter of the tree and are carried for considerable time (in some cases, over 12 months from fruit set to final harvest), there are few opportunities for pruning that do not risk damage to fruit.
- One option for reducing tree size that has been used successfully in other tree crops is dwarfing rootstocks. However, no dwarfing rootstocks suitable for commercial avocado orchards have yet been found.
- When establishing an orchard, land is generally the highest value input and growers need to maximise the return per hectare in as short a time as possible. The standard approach is to plant trees at a higher than normal density (up to 400 trees/ha). Densities of up to 2000 trees/ha are being tried in California, but these are not considered suitable for Australian conditions. When planted at higher densities, trees will soon

grow into each other unless canopy management is practised. Once the side canopies meet, light penetration into the orchard is significantly reduced and, as a result, the fruiting surface migrates to the tops of trees. This reduces fruit yield, size and quality, makes pest and disease control more difficult and increases the costs of harvesting. Poor light penetration also reduces growth of the interrow grass sward, increasing the risk of soil erosion between the tree rows.

- Avocado branches are highly susceptible to sunburn. Heavy pruning exposes large limbs to the sun, and these limbs need to be protected by applying whitewash, white plastic paint (**not** mineral-based paint) or a 5:1 mixture of talc and bentonite in water. A common talc:bentonite mixture is T63B talc and Truebond MW® in water. Seek advice on mixing rates and directions before proceeding.
- One of the most effective ways to minimise canopy growth is to maximise fruit load because a tree carrying a heavy crop has fewer resources to put into vegetative growth. Careful management of nitrogen is the key to maintaining a good balance between fruit production and vegetative growth.

Because of these issues and difficulties, several systems of canopy management or tree size control have been proposed. Their benefits depend on individual circumstances. However, they all aim to keep tree sizes manageable, maximising light interception and penetration, and avoiding the loss of too much fruit during pruning.

To do this, a well-defined strategy needs to be decided before the orchard is planted. This involves two important processes:

1. **Tree spacing analysis**. Will a high density (250 to 400 trees/ha), medium density (100 to 250 tress/ha) or low density (50 to 100 trees/ha) orchard be planted? A high density planting makes optimal use of the land available and generates greater cash flow in the early years. However, trees will need to be either thinned or pruned heavily before crowding begins. Regular pruning is then required for the life of the orchard. A low density planting removes the need for tree thinning and major pruning, but has low cash flow in the early years. It also produces larger trees, which increase picking costs, reduce picker safety, and may lower fruit yield and quality due to the greater difficulty in effectively spraying trees.
2. **Tree pruning system**. Depending on the tree spacing selected, what tree thinning and/or pruning system will be adopted? Options include tree removal (perhaps with transplanting), rotational staghorning, selective limb removal and hedgerowing. It is important to consider them before planting so that subsequent labour and machinery requirements can be factored into the analysis.

'Rules of thumb' for tree size

Three rules of thumb about tree size are commonly applied to orchard crops. These are aimed at achieving optimum illumination of the potential fruiting wood across the orchard canopy. The canopy management systems that follow are built around these rules of thumb.

Rule of thumb 1: The height of the tree should not exceed 80% of the distance between the tree rows (Table 8).

Table 8. *Relationship between tree height and distance between rows*

Distance between rows (m)	Suggested maximum tree height (m)
10	8
8	6.5
7	5.5
6	5
5	4

Rule of thumb 2: Tree height should be less than 2.5 times the width of the canopy-free interrow laneway or alley (Table 9).

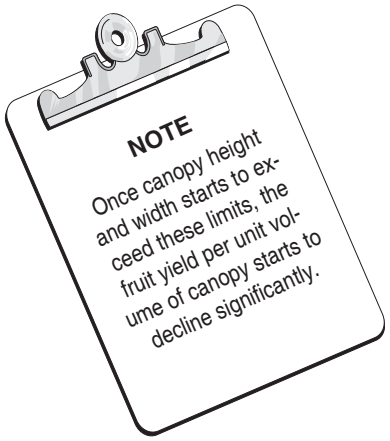


Table 9*. Relationship between tree height and width of laneway*

Canopy-free laneway between rows (m)	Suggested maximum tree height (m)
1	2.5
2	5
3	7.5

Rule of thumb 3: No part of the tree canopy should be more than 2 to 2.5 m from direct sunlight. This effectively means that the maximum canopy width should be 4 to 5 m. This may be difficult in practice but is a relevant point.

Tree spacing

The tree spacing selected will determine the type and frequency of canopy management practices. Orchards on closer spacings in good growing conditions will require a more intensive program of canopy management and will require it sooner. Tree spacing is largely determined by the management style, growing environment and variety. However, there are several important points that need to be considered.

- **Variety**. Varieties such as Fuerte and Sharwil are very vigorous and quickly grow into large trees. At the opposite end of the spectrum are Wurtz and Gwen, which are slower growing, even to the extent of being regarded as semi-dwarf. More vigorous varieties need to be planted at wider spacings.
- **Location.** In the warmer subtropical areas such as the Atherton Tableland and Bundaberg–Childers, trees will grow much faster than in Sunraysia–Riverland and south-west Western Australia. Growers in the cooler regions can use closer spacings. However, orchards in southern Australia receive lower light intensities and are less tolerant of overcrowding.
- **Management style.** If avocado growing is to be a part-time, retirement or life-style operation where intensive management is more difficult, the grower is well advised to plant at wider spacings. However, it is important not to lose sight of the increased safety risks and costs of harvesting large trees. Wider spacings allow more flexibility in the timing of canopy management practices. On the other hand, if earlier cash flow and maximum returns are critical, then closer spacing should be considered.
- **Pest and disease control**. The ability to achieve good spray coverage is very important for effective control of diseases such as anthracnose and insects such as leafrollers and fruitspotting bug. It is easier to achieve good spray coverage in smaller, more open canopies.
- **Soil type, nutrition and irrigation practices**. Orchards on deep, fertile

volcanic soils will grow faster than those on less fertile soils. A similar situation exists for trees grown under high levels of fertiliser and water management. The faster the growth, the earlier and more regular the need for canopy management practices.

- **Rootstock.** Some seedling rootstocks produce more vigorous trees. For example, seedling Velvick produces more vigorous trees than seedling Duke 7. It is important that growers ascertain what rootstock is being used and factor this into their spacing decision.

more info
Common tree spacings
Section 3 page 7

Tree thinning

Tree thinning was the first serious attempt at canopy management in avocado orchards and was first promoted in California. It suits high density planting of 250 to 400 trees/ha. Depending on initial tree spacing, tree thinning can involve the removal of alternate rows of trees, the removal of alternate trees within the rows, or the removal of trees on the diagonal in square plantings. The removal of trees on the diagonal in 6 x 6 m or 7 x 7 m square grid plantings (choice depends on tree growth rate) is probably the most efficient with respect to both light interception and orchard access once thinning begins. It involves changing the row direction and so is only feasible where slope and other factors allow this. However, it does present some difficulties. For example, the irrigation laterals would need to be re-located to the new row and surface drains may need to be re-constructed. Full details on the process including illustrations can be found in *Growing the Crop*.

more info
Tree thinning
Section 3 page 36

NOTE
Removal of trees on the diagonal may not be feasible for orchards planted on mounded rows. The change of row direction created makes machinery movement through the orchard difficult.

An advantage of tree thinning is that canopies of permanent trees in the orchard remain undisturbed and therefore maintain good fruit production. There is only a small decline in yield per hectare and only in the year immediately following thinning.

Staghorning

Staghorning is a process where mature trees that have become too large to be effectively managed are pruned back to a stump about 1 m high and allowed to re-grow (Figure 13). Note that the cut needs to be at a point above the graft, so that the scion variety re-grows. Experience has shown that Hass trees treated this way can produce a small commercial crop in the third year after staghorning.

The full staghorning procedure can be found in *Growing the Crop* page 36.

The initial concept was to staghorn alternate rows on the understanding that this would maintain cash flow until the staghorned trees began cropping again. However, experience has shown that this is relatively ineffective as the remaining trees quickly fill in the space, reducing the light reaching the staghorned rows. This causes the regrowth to become elongated and by the time fruiting recommences on the staghorned trees, they can easily be two-thirds of their original size. Blocks with alternate tall and short trees are also more difficult to manage.

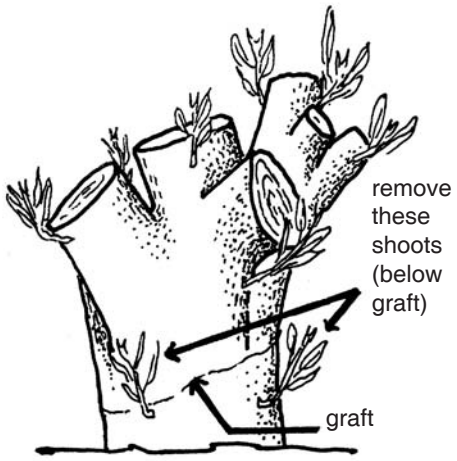


***Figure 13**. A staghorned tree.*

As a result, the current recommendation is to staghorn all trees in a block or section of the orchard. This maintains an even light regime for the regrowing trees. To maintain cash flow, sections of the orchard can be staghorned at intervals so that within the orchard, there are sections at various stages

of production and regrowth. Some growers maintain an ongoing orchard 'recycling' program with a portion of the orchard staghorned each year.

In California and Florida where growing conditions are different to Australia, a limited form of staghorning is practised. Trees are cut back to about two-thirds of their original size. This redistributes the cropping, with most of the fruit being carried in the lower and middle third of the canopy instead of at the top of the tree.

Selective limb removal

Selective limb removal is used to maintain tree size and interrow access in the medium term. Most growers practise it to some degree. Eventually, it will need to be combined with tree thinning, staghorning or hedgerowing.

There are four main types of selective limb removal:

- As trees grow, some limbs protrude into the laneway, reducing orchard access. These limbs should be removed at a point close to the main trunk.
- Some degree of tree height control can be achieved by selective limb removal. Limbs are removed back to a major horizontal branch. This helps reduce the vigour of regrowth, but works best with heavy cropping varieties where regrowth is naturally less vigorous.
- Low branches, where fruit is likely to contact the ground, should be removed.
- From time to time, removal of a major limb in the centre northern part of the tree will improve light penetration and rejuvenate productivity.

Selective limb removal is also used in hedgrerow pruning to open up the canopy at the hedge trimming face (see below).

Hedgerow pruning

For management convenience, most growers prefer a hedgerow layout rather than a square planting. This allows trees to grow together within the row while maintaining a laneway or alley between the rows for machinery access.

Hedgerow pruning attempts to shape the hedgerow into a uniformly pruned row of trees that produce a plane of foliage to maximise light interception and subsequent fruit production. This also illuminates the laneway, maintaining growth of the grass cover and preventing soil erosion. The aim is to produce the following characteristics:

- Row direction: north-south;
- Shape of row: A-shaped in cross-section (narrow at top and broad at the base with an angle of cut 22° to the vertical) to enhance light penetration down the side faces of the row (Figure 14);
- Tree height: up to 6 m (economical size to manage);
- Tree canopy diameter at base: 4.5 to 5 m;
- Spacing between rows: 7.5 to 8 m (4.5 to 5 m tree canopy diameter plus 3 m laneway);
- Tree spacing within rows: as close as 4 m.

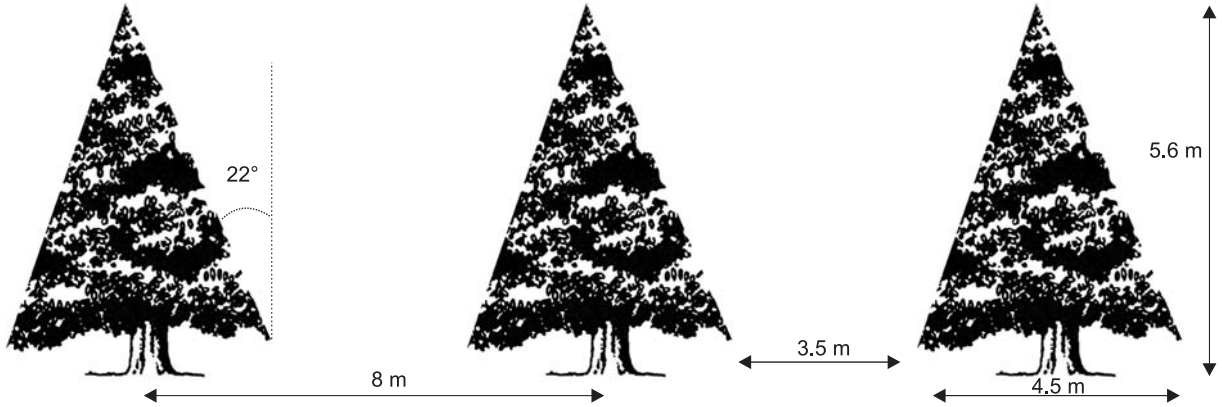


***Figure 14**. Desired tree shape, spacing and dimensions for hedgerow pruning*

more info
Hedgerow pruning
Section 3 page 37

Full details of the hedgerow pruning process can be found in *Growing the Crop*.

The hedgerowing system proposed here is based on rows running in a north-south direction. This is best for maximum production. However, where this is not possible, and rows have to be run east-west, we suggest that different pruning angles for the hedgerow be evaluated. To maximise light interception, the suggested arrangement is pruning the northern side of the row (facing the sun in winter) at a wider angle to the vertical, while pruning the southern or opposite side at an angle close to vertical (Figure 15).

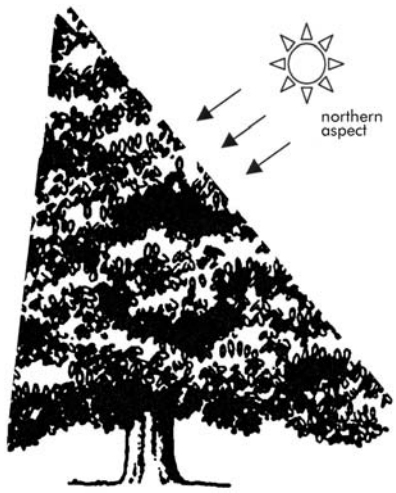
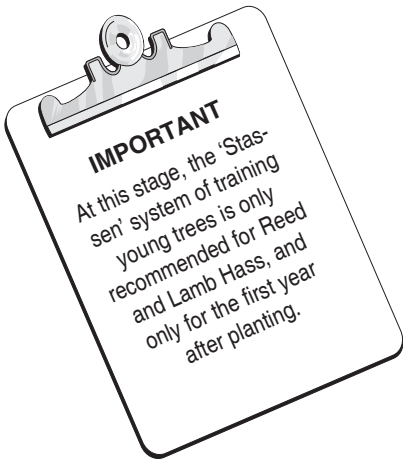


***Figure 15.** Pruning angles for hedgerows planted in an east-west direction*

Training young trees—the 'Stassen' system

In developing the hedgerow pruning system, the focus has been on training young trees so that they better suit the pyramid shaping applied later in the orchard. In South Africa, the 'Stassen' system recommends pruning young trees to a central leader. This aims to produce a single central trunk with lateral branches at intervals along its length (Figure 17). This contrasts with the normal structure of trees with several main limbs radiating from a short trunk (Figure 18).

The rationale behind the 'Stassen' system is that trees trained to a central leader should naturally form a pyramid-like shape similar to the pruned shape of the hedgerow. When the initial shaping cut is made, less foliage needs to be removed than with the more rounded, standard tree shape.



However, experience to date has shown that the 'Stassen' system is really only suited to those varieties that are more naturally upright in their growth habit (for example, Reed and Lamb Hass). We do not recommend it for other varieties with natural spreading growth habits as early production is enhanced by tipping shoots to increase the complexity in trees.

For Reed and Lamb Hass trees, use these steps for training young trees under the 'Stassen' system.

- In the nursery, the growing point at the top of the tree must **NOT** be tipped.

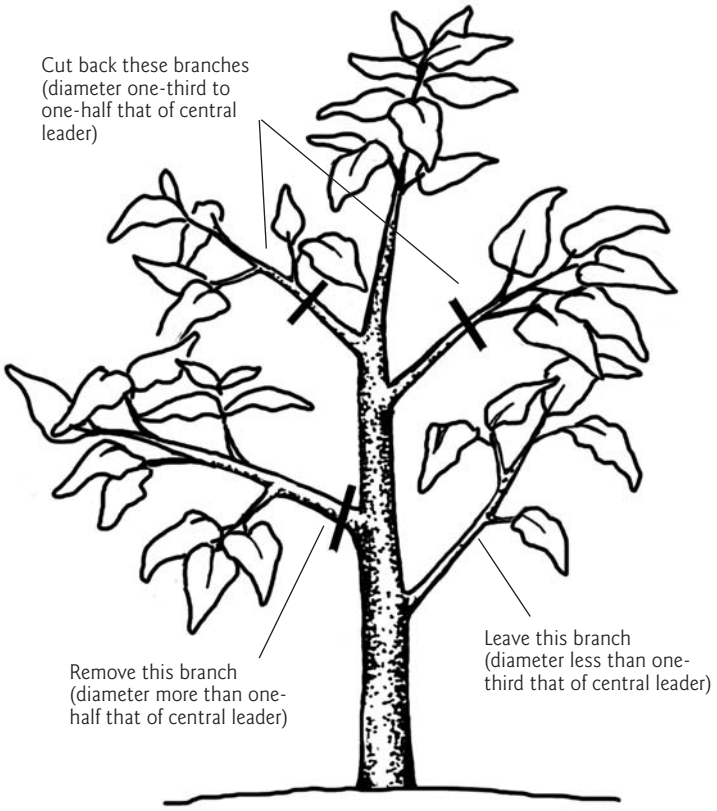


Figure 16. *Training of young trees using the 'Stassen' system*

- After planting, the aim is to break the apical dominance amongst the **side** branches. This is achieved by following these three rules for the first year after planting (Figure 16):
  1. If the diameter of the side branch is more than half the diameter of the central leader at the point of attachment, the side branch is completely removed at its base.
  2. If the diameter of the side branch is between one third and one half of the diameter of the central leader at the point of attachment, the side branch is cut back by about half its length.
  3. If the diameter of the side branch is less than one third of the diameter of the central leader at the point of attachment, the side branch is left untouched.
- Any fruit that are set near the top of the central leader are removed, to prevent the central leader from bending over and losing apical dominance.

Figure 17. *Tree trained to a central leader*

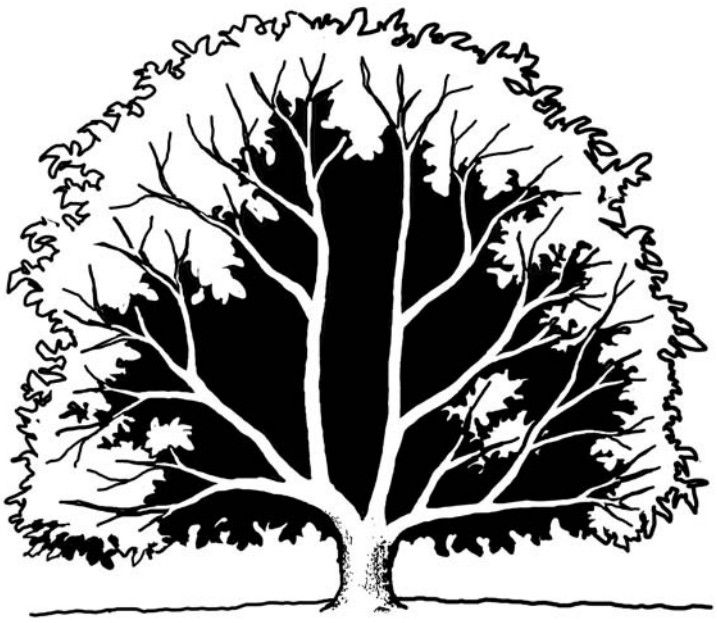


Figure 18*. Standard tree shape*

Managing crop production: Root rot management

Phytophthora root rot is the most serious disease of avocados and arguably the most important management issue for growers. It is present in almost every Australian avocado orchard where, under the right conditions, it may cause rapid and serious losses.

Major emphasis is needed in keeping it under control. This involves an integrated management program involving seven main components.

Understanding the disease

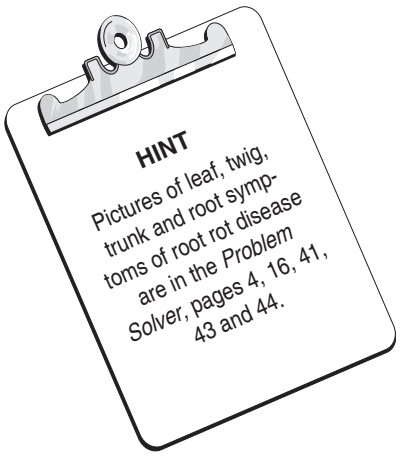
Cause

Phytophthora root rot disease is caused by the soil-borne fungus *Phytophthora cinnamomi.*

Occurrence

The fungus is widespread throughout most of the avocado growing areas of Australia, causing substantial damage to trees in the wetter production areas of Queensland, northern New South Wales and the lower south-west of Western Australia. In other states, it is of slightly less importance because of less favourable environmental conditions. However, the fungus is not necessarily present in all soils, particularly if there has been no previous history of host plants grown at the site, and irrigation water used is not from infested catchments.

The fungus affects over 900 plant species including avocado, pineapple, macadamia, stonefruit and a wide range of ornamentals. Of all the affected species, avocado is one of the most susceptible.



Symptoms

Leaves on affected trees are pale green and wilted, and fall readily. Shoots die back from the tips; the canopy thins out from the top of the tree, and eventually the tree is reduced to a bare framework of dying branches. Trees may take a few months to several years to die.

In mildly affected trees with reasonable leaf cover, a significant proportion of the leaves may fall during flowering. Declining trees sometimes set large crops of small fruit.

Affected roots are black, decayed and few in number compared with healthy trees, which have plentiful white feeder roots.

A weeping stem canker may occur on the lower trunk. The white exudate often associated with the canker is made up of dried crystals of a type of tree sugar called persitol.

SIMILAR DISEASE SYMPTOMS

Symptoms of two other disease problems are often confused with those of Phytophthora root rot. ***A basidiomycete wood rot fungus*** *can cause similar root death and wilting. The fungus enters trees through untreated major pruning cuts. It is more likely in areas adjacent to rainforest. It can be distinguished from Phytophthora root rot by the presence of shelf-like hemispherically shaped fruiting bodies on the lower trunk of affected trees. It also generally affects only part of the tree and major roots, as well as a confined zone of the feeder roots.*

To prevent wood rot disease, make sure all roots and other tree residues are removed from newly cleared land before planting, and treat all major pruning cuts with a mixture of white plastic paint and copper fungicide. This is particularly important when staghorning. Make pruning cuts at an angle to allow rainwater to drain away freely.

Verticillium wilt *can cause similar wilting. The fungus enters the tree through the roots and clogs up the water-conducting tissues of the trunk and branches. It can be distinguished from Phytophthora root rot by the brown discolouration of the water-conducting tissues. It also generally affects only part of the tree. Pictures of symptoms and suggested treatments can be found in the* Problem Solver *on pages 8 and 40.*

Source of infection and spread

The fungus causing Phytophthora root rot belongs to a group of fungi referred to as water moulds. These moulds require free water to produce spores and infect roots. Zoospores, the main spore type produced, are tiny swimming spores which are strongly attracted to avocado roots by root exudates.

The fungus is commonly introduced into the orchard by diseased nursery trees. It can also be spread in soil on boots, tools and vehicles, in storm water draining from an adjacent infested property, or through irrigation water collected from an infested catchment.

When the fungus is present, the soil and climatic conditions play an important role in how quickly it progresses. Under high summer rainfall conditions, trees may decline rapidly in sandy soils low in nutrients and organic matter, but show few above-ground symptoms on deep, organic-rich, volcanic soils. The latter soils are known as suppressive soils and under good management maintain a natural high population of micro-organisms which help to keep the fungus in check.

Root rot may progress more rapidly when nutrient and water requirements of trees are not being met. It is important to maintain the correct balance of nutrients and water throughout the life of the orchard.

The integrated root rot management program

Experience has shown that no single management measure is effective for Phytophthora root rot for very long. The more serious the disease problem, the greater the necessity to use several management measures in an integrated fashion. The Phytophthora root rot disease management program consists of seven elements (Figure 19).

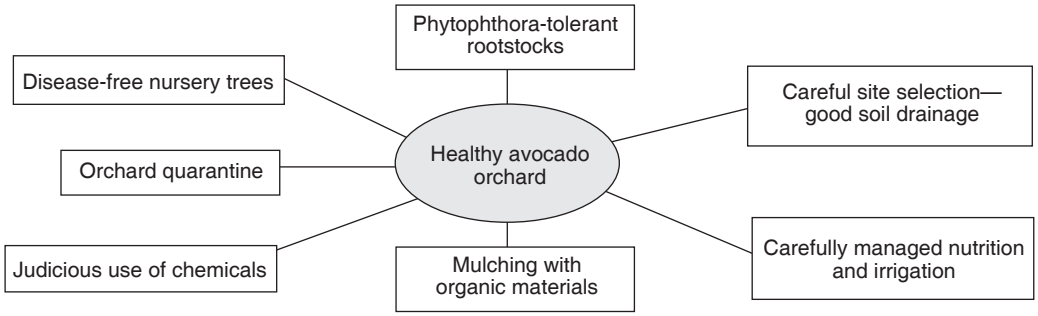


Figure 19. *The seven elements of the integrated program to manage root rot disease*

Here are some brief details on the seven elements.

1. Soil drainage

more info
Selecting the right site
This section page 5

Before planting, carefully assess the drainage characteristics of the soil to make sure internal drainage is adequate. Information on how to assess internal drainage is in 'Selecting the Right Site'.

Only plant avocado trees in soils with sufficient drainage capacity to cope with your rainfall. Besides root rot disease, trees can also be quickly killed by waterlogging if planted in soils with inadequate soil drainage. Where soil depth is marginally less than what is required, mounding along the rows may be advantageous. However, mounds should not inhibit machinery access and movement nor should they dam up water. Where possible, orientate rows so that interrow spaces freely drain excess water during heavy rainfall.

2. Orchard quarantine

To minimise further introduction of the root rot fungus into the orchard, restrict unnecessary vehicle and people movement into the orchard. Footbaths at convenient access points are simple and effective measures. In the long term, these measures need to be combined with runoff control structures that prevent soil and water from outside moving into the orchard.

3. Disease free nursery trees

Plant only disease-free nursery trees that have been propagated in sterilised potting mixture from pathogen-free seed, and irrigated with Phytophthora-free water. Such trees are available from nurseries accredited under the Avocado Nursery Voluntary Accreditation Scheme (ANVAS) supervised by the Australian Avocado Growers' Federation. These nurseries follow strict hygiene procedures to ensure planting material is of high quality and free from Phytophthora root rot and other diseases such as sunblotch viroid.

HINT
An up-to-date list of accredited nurseries is published in the industry magazine *Talking Avocados*. Alternatively, contact the Australian Avocado Growers' Federation, see *Contacts*, Section 6.

Where possible, plant trees within a short time of delivery. Where trees need to be stored for a short period, hold them in a well-protected area and preferably off the ground away from soil. Weldmesh benches on concrete blocks or bricks are ideal. Alternatively store on a raised bed of coarse gravel laid on the ground. Do not store trees on impervious flat surfaces such as plastic sheeting or concrete where water can pool around the base of pots and infection can spread from pot to pot. Also, do not store under older avocado trees or near domestic gardens, both of which are good sources of root rot infection. Use tank or town water to water nursery trees, not dam water as it can carry spores of the root rot fungus.

4. Tolerant rootstocks

Some rootstocks have a degree of tolerance to Phytophthora root rot, mainly through an ability to rapidly regenerate feeder roots after damage. For example, in subtropical regions, Velvick and Duke 7 appear to have some tolerance. The more tolerant rootstocks are recommended, particularly in the wetter areas of Queensland and New South Wales where disease pressure is highest.

5. Mulching and cover cropping

Mulching and cover cropping improves the organic matter levels and physical condition of the soil. It is an important but often neglected element of the integrated root rot management program.

Mulching improves weed control, conserves soil moisture, stimulates feeder root development and enhances the activity of micro-organisms antagonistic to the root rot fungus.

Start mulching young trees immediately after planting and continue until trees are large enough to be able to provide a deep litter cover from natural leaf fall. Mulch to a depth of about 100 to 150 mm, and in young trees over an area to about 75 cm from the trunk. As trees grow, extend the mulched area outwards, maintaining it to 50 cm or so beyond the dripline. Do not place mulch against the trunk as this favours trunk canker.

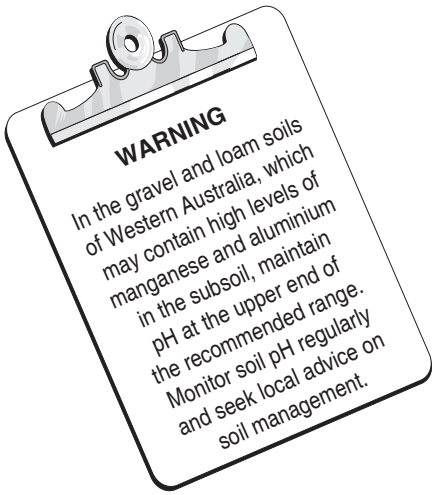
Use a coarse material that drains well such as wheat or barley straw, sorghum stubble or composted pinebark. Bagasse, sawdust and mill mud (filterpress) are not recommended as mulch materials in wet areas because they are too fine and tend to hold too much water. However, mill mud is suitable for drier areas and is also beneficial as an organic fertiliser for young trees, provided it is used sparingly.

Cover cropping improves soil aeration, water-holding capacity, nutrient recycling and suppression of the root rot fungus through enhanced activity of beneficial micro-organisms.

In the summer rainfall subtropical areas, cover cropping is recommended from one year before planting through to when the trees begin cropping (three to four years old). After planting, the cover crop is grown in the interrow space and the area cultivated progressively reduced as the trees grow. This assumes that the interrow does not have to be maintained in a permanently grassed condition to prevent erosion, as would be the case on steeper slopes.

During summer, use forage sorghum (preferably a sweet sorghum hybrid such as Jumbo, which has a longer season and coarser stems) or hybrid millet (for example Nutrifeed). Slash just before it goes to seed (two to three slashings per season are possible from sorghum) and direct the slashings along and under the tree row. During winter, use a cereal such as oats, barley, triticale or rye, preferably with a legume such as lupin. Figure 20 shows the use of a cover crop of lupins in a newly-planted orchard. Seek local advice on the best varieties of the various cover crops for your region.

***Figure 20**. A cover crop of lupins being grown between rows and trees in a newly-planted orchard*



6. Fertiliser and irrigation management

Soil pH and fertiliser use may have a significant effect on the activity of the root rot fungus. The following practices are recommended:

- Maintain soil pH at about 5.0 to 5.5 (1:5 water) or 4.2 to 4.7 (1:5 $CaCl_2$) unless soil manganese levels exceed 40 ppm. Do not use lime or dolomite unless pH falls below these levels.
- Use regular soil and leaf analysis to ensure adequate phosphorus, calcium and boron levels are maintained in the soil. Optimum levels of these nutrients help achieve good root growth.
- Where possible, avoid the use of nitrate and chloride fertilisers. Instead use ammonium and sulphate types as these produce a less favourable environment for the fungus. However, as these fertilisers acidify the soil, regularly monitor soil pH, particularly in soils with low organic matter levels and particularly at depth.

Similarly, irrigation management may significantly affect root rot development. Overwatering can increase the severity of the disease while moisture stress is believed to increase the susceptibility of roots to infection. To avoid over and under-watering, use soil moisture monitoring devices such as tensiometers or capacitance probes to carefully schedule irrigation rates and timing.

7. Chemical control

Two effective fungicides are available for the chemical control of Phytophthora root rot disease.

Metalaxyl granules at and soon after planting

To provide protection from Phytophthora root rot during the first year of establishment, treat tree sites with metalaxyl granules at planting and 8 and 12 weeks later. Follow label directions.

Regular trunk injection or foliar spraying with phosphonate fungicide

From the second year onwards, we recommend that all trees in the orchard be treated every year with phosphonate fungicide. Do not assume that apparently healthy trees do not have root rot. Full details on the treatments are in *Growing the Crop*.

more info
Chemical control of root rot
Section 3 page 24

A foliar spray with phosphonate fungicide is also useful on nursery trees one to two weeks before planting. This helps to protect the roots immediately after planting.

Other useful practices

Another useful practice to help minimise the impact of root rot disease is to remove the fruit from unthrifty trees, particularly young trees. This helps the tree cope with the disease by removing a significant source of competition for resources, thereby facilitating replacement root growth.

Managing crop production: Mulching

The avocado is a rainforest tree with a relatively shallow root system adapted to feeding from the soil surface. This makes avocado trees highly susceptible to moisture stress. Mulching provides many benefits and is vital for long-term orchard health and productivity.

The benefits of mulching

A summary of the benefits

- Avocados have evolved in subtropical rainforests where their feeder roots proliferate in decomposing litter. As a result, trees have a relatively shallow root system adapted to feeding from the surface layer of soil and mulch. About 80% of the white feeder root system is found in the top 45 cm of soil and mulch. Roots also have few root hairs, an important feature in water uptake. Consequently, trees are highly susceptible to moisture stress. Mulch insulates the soil from the sun and wind, reducing evaporation and moderating temperatures in the root zone. Water and heat stress are therefore reduced.
- Mulch improves the physical characteristics of the soil—its structure, porosity and aeration. It builds up the organic matter level in the soil, producing a more open soil structure, which enhances water penetration and soil water storage. By enhancing water penetration, water runoff and soil erosion are reduced. Improved soil structure reduces the potential for soil compaction and provides a better physical environment for root growth.
- Mulch improves the chemical characteristics of the soil. The higher organic matter level produced enhances the capacity of the soil to store and release nutrients (its cation exchange capacity). It also allows the roots to 'bypass' complex soil chemistry that may tie up elements such as zinc and phosphorus, and instead recover these from the mulch and humus. As mulch usually supplies small amounts of nitrogen and other nutrients, artificial fertiliser use can be reduced, saving money and reducing the potential of 'free' nitrates to pollute the groundwater.

- Mulch improves the biological characteristics of the soil by providing food substrate for beneficial soil organisms as well as a better physical environment for their development. As a result, the soil microflora becomes more diverse and more abundant. This helps suppress harmful disease organisms such as the Phytophthora root rot fungus, as well as significantly improving nutrient recycling and root health.
- By suppressing or preventing weed growth, mulch also reduces competition from weeds for nutrients and water, and cuts the cost of herbicide spraying.

South African experiences

Two recent mulching trials in South Africa confirmed these benefits.

The first, a three-year study using one application of composted pinebark, showed an average yield improvement over the three years of 22.6% and an average fruit weight increase of 6.6%. The fruit weight increase meant that the number of fruit in the higher priced fruit size range increased by 45%. The study also showed that the seed coat remained viable for longer (contributing to the greater fruit size), there was less ringneck and greater levels of root activity. The mulch was applied at a rate of 1½ cub. m per tree to a depth of 15 cm.

Reference: Moore-Gordon, C., Cowan, A.K. & Wolstenholme, B.N. (1997), *Mulching of avocado orchards to increase Hass yield and fruit size and boost financial rewards—a three-season summary of research findings*, *South African Avocado Growers' Association Yearbook*, 20: 46–49.

The second study, using a mulch of 10 cm of composted mill mud (filter press from a sugar mill), doubled yield in the second year of the trial from 11.6 t/ha in untreated trees to 23.2 t/ha in mulched trees. Average fruit size increased by 38 g in the first year and 20 g in the second year of the trial. These exceptional results were attributed to the effects of mulching as well as the mill mud's organic fertiliser benefit.

Reference: van Niekerk, W., Wolstenholme, B.N. & Johnston, M.A. (1999), *Mulching and potassium relationships in Hass avocados to increase yield and fruit size, South African Avocado Growers' Association Yearbook*, 22: 110–114.

Cost/benefit analysis

Costs and benefits will vary from site to site, but it is not difficult to show improved returns if trees are mulched well. Here is a conservative example. Compare the increases used here with those measured in the South African examples above.

If the yield of an existing orchard producing 10 t/ha is increased by a conservative 15% to 11.5 t/ha, and the average price received per tray is increased from $12 to $13 as a result of better fruit size, then the overall benefit is calculated at $5000/ha.
The cost of materials using three bales of straw/tree/year (at $2/bale) on an orchard with 312 trees/ha is $1900/ha.
The cost of labour to drop the bales in the orchard and spread the mulch under the trees is calculated at $400/ha (33 hours of labour at $12/hour).
Total cost is around $2300/ha.
The direct benefit is about $2700/ha, but this does not consider the longer-term benefits from healthier trees, and reduced irrigation and fertiliser costs.

Potential pitfalls

Mulching has some potential problems, which must be considered before proceeding. These include:

- An increased frost hazard (loose mulch prevents the sun from heating the soil during the day, which subsequently helps to reduce the temperature at ground level during the night).
- An increased fire hazard under hot dry conditions (dry mulch burns well and avocado bark has little or no resistance to heat).
- A nitrogen imbalance (too high or too low) if unsuitable mulching materials are used.
- Potential infection of trees with Verticillium wilt disease carried in peanut shell mulch.
- Collar rot disease or trunk canker if mulching material is placed against the trunk.

Suitable mulching materials and their use

Mulch characteristics

Not every type of mulch is suitable for avocados. The two most important properties are coarseness and the carbon:nitrogen (C:N) ratio.

Coarseness. Materials should be coarse enough to break down slowly and allow free drainage of water through them. These properties are generally found in materials that are fibrous, stalky, straw-like or chunky.

Materials that are too fine, such as sawdust, bagasse and lawn clippings, tend to form a barrier that initially prevents water penetration. However, once wet, they become soggy, dry slowly and keep the underlying soil excessively wet. In wetter environments, coarser materials should be used as these take longer to break down. Also, fresh hardwood sawdust is toxic to avocados because of its resin content.

Carbon:nitrogen (C:N) ratio. Ideally for avocados, the C:N ratio should range from about 100:1 to 20:1 (shaded section in Table 10). Materials with a C:N ratio significantly lower than the recommended range (for example lucerne hay), tend to decompose too rapidly and raise nitrogen levels too high. Materials with a C:N ratio that is too high can cause a nitrogen draw-down effect unless extra nitrogen fertiliser is applied (the material takes nitrogen from the soil to decompose, thus starving the tree). A combination of different materials can often be used to achieve the desired C:N ratio and coarseness.

***Table 10**. Carbon:nitrogen (C:N) ratios in a range of dried materials (after Handreck, K.A. & Black, N.D. (1994*), Growing media for ornamental plants and turf *(revised edition), University of New South Wales Press.*

Material	Carbon:nitrogen (C:N) ratio
Pinus radiata sawdust	550
Cardboard	500
Pinus radiata bark	500
Eucalyptus sawdust	500
Eucalyptus bark	250
Bagasse	120
Woody prunings	100
Composted *Pinus radiata* bark	100
Wheat or oats straw	100
Sugarcane tops	80 – 100
Mature leaves	60
Composted pine bark	30 – 40
Corn stalks	33
Mill mud (filter press)*	23
Grasses	22
Mixed weeds	19
Cow manure	15
Lucerne hay	13
Peanut shells	12
Poultry litter	10 – 11
Poultry droppings	7
Pig manure	5

* This figure is for mill mud only. Some sugar mills blend fly ash with mill mud and this mixture will have a different C:N ratio. In wetter areas of Queensland and northern New South Wales, mill mud may not be suitable for mulching. However, it is suitable for drier areas such as Bundaberg and is also beneficial as an organic fertiliser for young trees, provided it is used sparingly.

Using mulches

If materials with a high C:N ratio are used (for example 100:1 and higher), either compost the material before application or apply extra nitrogen to the trees to offset the draw-down effect. Chipped avocado prunings, a natural choice for some growers, fall into this category.

If the material is very coarse (for example, loose branches), then this is not critical because the rate of breakdown is very slow. The practice of placing whole pruned avocado logs under the tree without chipping falls into this category. These logs will eventually rot down but in the meantime can be a hazard for pickers at harvest time.

Locally available mulching materials should always be investigated. Sugar cane tops are popular, but they have a reputation for lowering soil pH more than other materials. This is not a problem as long as pH is monitored and lime or dolomite is applied as required. Mill mud (filter press) from sugar mills is a popular mulch where it is available and studies have shown excellent results in terms of yield and fruit size improvement. This is thought to be due to a combination of its nutritional properties, water-holding capacity and ability to suppress root rot. Studies have shown that mill mud releases its nitrogen slowly (about one-third in the first year, one-third in the second year and one-third in the third year). Used too thickly, however, its fineness may cause a problem in wetter environments.

Applying mulch

It is best to apply mulch after the wet season, with the aim of having it in an advanced stage of decomposition before the onset of the next wet season rains. In frost-prone areas, apply mulch in late winter or early spring. Where necessary, replenish it during the year. A depth of 100 to 150 mm is ideal and the mulch should completely cover the under-tree area and extend about 50 cm beyond the dripline. Keep it about 10 cm away from the trunk. Don't forget to add extra nitrogen if using materials with a high C:N ratio.

Growing your own mulch

Growers are often deterred from using mulch because of the cost of material, lack of local availability (and therefore high transport costs) and the cost of labour to spread it.

Growing your own mulch can offer a solution to these problems. Mulch can be grown in the interrow space within the orchard while trees are small and/or in adjacent areas. A crop of forage sorghum grown between the tree rows before or during planting can supply enough mulch for at least the first year of the orchard. To reduce the cost of spreading, many growers have modified slashers to direct slashings from the interrow areas in under the trees. This way, the mulch is topped up at no extra cost every time the orchard is slashed. Don't underestimate the amount of mulch that can be grown in the interrow area and deposited under the trees by this method during the first few years of the orchard.

Suggested crops that can be grown include:

- **Spring/summer planting**: Forage sorghum such as Jumbo (a sweet sorghum hybrid with a long growth season and coarse stem) or hybrid millet such as Nutrifeed.
- **Autumn/winter planting**: Oats, barley, triticale, rye grass or lupin varieties such as Kalya or Merrit.

If crops such as sorghum are not grown in the interrow, use the grass clippings from the grass sward. The sward can be enriched by planting Rhodes grass, setaria, panic, clover or kikuyu. Watering and fertilising the interrow area can also increase the bulk of material available. Although grass clippings are not an ideal mulch because of their fineness and low C:N ratio, adding small amounts at regular intervals does not pose a problem, especially when it is added to the existing leaf litter.

Another option is to grow a low-input crop of natural coarse-stemmed grass such as Rhodes grass, setaria or panic on second grade ground near the orchard, and either forage harvest it for immediate use or bale it for later use. Forage harvesting and baling equipment could be shared amongst a group of growers, particularly since timing of the operation is not critical. An advantage of round bales is that they can be unrolled down the row.

Living mulches

Where slope, soil type or rainfall increase the risk of soil erosion, growing living mulch under and between the trees could be considered. Living mulch species must be perennial, hardy, low growing, non-climbing, tolerant of shade, and dense enough to smother weed competition.

Possible species include Amarillo pinto peanut (*Arachis pintoi*), smothergrass (*Dactyloctenium australe*), Shadegro® and Maku lotus (*Lotus pendunculatus*). marillo pinto peanut (Figure 21) is a legume that can supply extra nitrogen into the orchard.

***Figure 21**. Amarillo pinto peanut*

Living mulches will compete to some extent with the avocado trees for water and nutrients, so extra amounts may be needed to compensate. For trees less than about three years old, some control of competitive growth may be necessary. However, in the long term, the advantages of nutrient recycling, increased organic matter and a reduction in soil loss will outweigh these disadvantages.

Further reading

Aitken, R. et al (1999), *Filter mud/ash—getting value for your investment*, BSES Sunshine Sugar Fact Sheet.

Firth, D.J. (2000), *Groundcovers for subtropical orchards*, Agfact H6.3.10, 3rd edition, NSW Agriculture, Alstonville.

Managing crop production: Nutrition management

Plant nutrition is one of the keys to achieving good orchard performance. Both deficiencies and excesses of plant nutrients can adversely affect fruit yield and quality. Nutrition also affects the ability of the tree to cope with root rot disease. Fertiliser use has to be carefully managed to ensure a balanced supply of all nutrients is maintained at the critical times during leaf growth and fruit development.

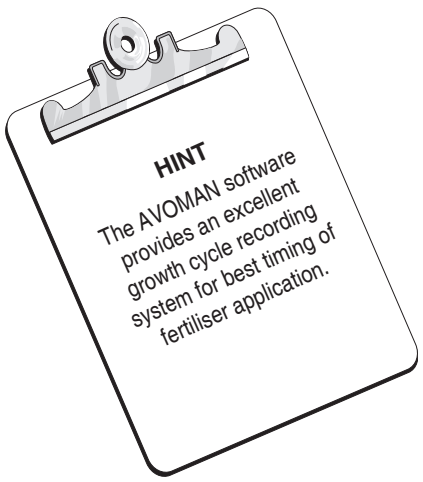
The importance of nutrition

Management of bearing avocado trees is a complex process. Leaf, root and flower/fruit growth depend on each other, but also compete for the tree's limited reserves of carbohydrates, nutrients and water. If this competition is not properly managed and the vegetative/reproductive balance gets out of step, fruit yield is ultimately reduced. The management of nutrition plays a vital role in maintaining the appropriate vegetative/reproductive balance.

Nutrition can also directly affect fruit quality. For example, high concentrations of calcium in fruit may reduce the incidence of diseases and flesh disorders.

The management of nutrition involves carefully managing the timing and quantity of fertiliser applied. Timing is important to ensure that fertiliser is applied at appropriate times in the growth cycle. Quantity is important to ensure fertiliser rates are adequate, but not excessive. For example, too much fertiliser (especially nitrogen) promotes excessive vigour, which may detrimentally affect flowering, fruit development and fruit drop. Good management of nutrition involves four key steps:

- **Understanding how the nutrients work**. Basic knowledge of each of the important nutrients and how they affect the tree is an important requirement in being able to manage a fertiliser program.
- **Getting the soil nutrients right before planting.** This involves doing a pre-plant soil analysis to ensure that nutrients can be brought to their optimum levels before planting. This is particularly important for the adjustment of insoluble nutrients such as phosphorus and calcium, which are difficult to adjust once the trees are in the ground.
- **Following the growth cycle of bearing trees**. Knowledge of the growth cycles and the way they are influenced by changes in weather, crop load and orchard operations allows the timing of fertiliser application to be customised to each variety or block to achieve its maximum potential.



- **Annual leaf and soil analysis in bearing trees**. Different varieties, different blocks of trees and different soil types may have different fertiliser needs. A single fertiliser rate across the orchard may be too much for some and too little for others. Leaf and soil analysis allows the fertiliser program to be fine-tuned to the needs of each block. Particular attention needs to be given to the management of nitrogen, boron, calcium, zinc and soil pH.

Understanding soil pH

__NOTE__: Commercial soil testing laboratories express soil pH results according to the testing procedure used: 1:5 water test or 1:5 $CaCl_2$ test. As the different test results require different interpretation, it is important to always differentiate which test is used.

Throughout this kit, soil pH results are generally always expressed using the 1:5 water test. for example, pH 5.5 (1:5 water test).

Soil acidity or alkalinity is measured on a pH scale which runs from 0 to 14. A pH of 7.0 is neutral; below this the soil is acid and above it alkaline. The pH scale is a logarithmic scale; soil with a pH of 5.0 is 10 times as acid as a soil with a pH of 6.0. The acidity or alkalinity of soil is important in the availability of essential mineral nutrients for plant growth. Some are less available at strongly acid pH levels while others are less available at alkaline pH levels (Figure 22). Below pH 4.5, some mineral toxicities can occur from the soil solution becoming saturated with minerals such as aluminium and manganese. On the other hand, when soil pH rises over 7.5 (more alkaline), many mineral nutrients become fixed and plant deficiencies may develop. In general, trace elements are most affected by high soil pH.

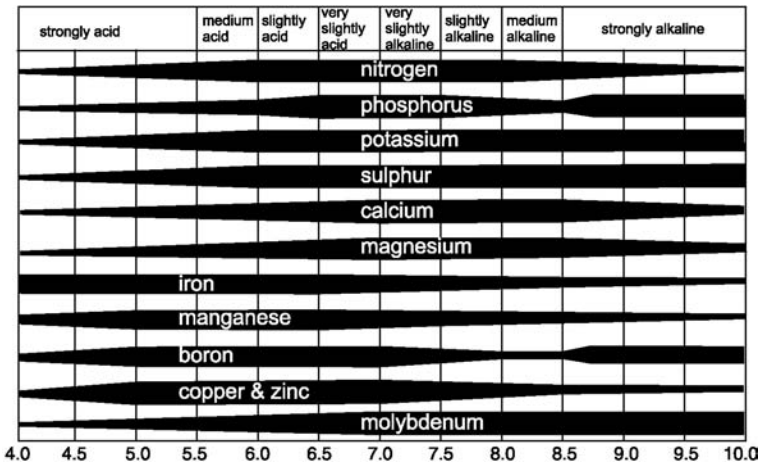


***Figure 22.** Effect of pH on nutrient availability*

Research has shown that under most conditions the optimum soil pH for growing avocados is between 5.0 and 5.5 (1:5 water test). This range appears to provide the best conditions for growth and fruit yield. However, where the soil manganese level is over 40 ppm, manganese becomes more available and may become toxic. This is generally only a problem in some production areas in subtropical eastern Australia. In this situation, the target soil pH should be 6.5 (1:5 water test). As high temperatures and higher soil moisture levels during summer increase the availability of manganese, samples taken at this time will show a higher level than at other times of the year.

__WARNING__: In the gravel and loam soils of Western Australia which may contain high levels of manganese and aluminium in the subsoil, maintain pH at the upper end of the 5.0 to 5.5 range (1:5 water).

Monitor soil pH regularly, particularly at depth (50 cm or more), and seek local advice on soil management.

Soil pH above 6.5 reduces the availability of trace elements such as boron, copper, iron and zinc. It also enhances Phytophthora root rot. Soil pH changes with time, generally becoming more acid when mineral fertilisers are used. Monitor soil pH annually and adjust where necessary.

The most common products used to increase soil pH are lime (calcium carbonate) and dolomite (a mixture of calcium and magnesium carbonates). Dolomite is used when soil magnesium levels are low. As pH correction can be a slow and difficult process unless liming materials are incorporated into the soil, it is important to adjust pH before it moves out of the desired range. In existing orchards where lime or dolomite cannot be physically incorporated into the soil, it is best to use liming materials with a high neutralising value and high fineness (particle size less than 75 microns or micrometres). The fineness allows the material to move more readily down through the soil profile to achieve the desired soil pH change throughout the root zone.

Where soil pH needs to be reduced (less common), elemental sulphur is most often used.

Understanding the individual nutrients

Note: The information provided here is not meant to be a comprehensive coverage, but instead outlines the key points that growers need to understand in managing fertiliser programs.

Nitrogen (N)

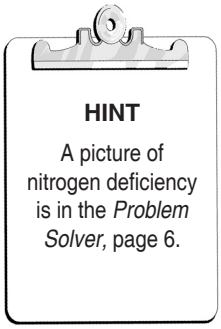
Function

- The most important nutrient for tree growth.
- A key component of chlorophyll (the green pigment in leaves), which is why nitrogen deficient trees are light green or yellow.
- An essential requirement for the synthesis of plant hormones, which control tree growth.
- When available in excess quantities, can promote strong vegetative growth at the expense of fruiting.

Behaviour in soil and plant

- Slowly released from the mineralisation of organic matter in the soil. A proportion of the tree's requirements will be met from the decomposition of the leaf litter under the tree.
- Very mobile in the soil and leaches very readily, particularly in high rainfall areas.
- A significant quantity is removed with the crop each year (about 3.6 kg of nitrogen for every tonne of fruit).
- Very mobile within the tree.
- Very dynamic relationship between leaf concentration and growth, so we recommend that leaf analysis be done in autumn, when the tree enters a dormant period and leaf nitrogen concentrations stabilise.

Deficiency/toxicity symptoms



HINT

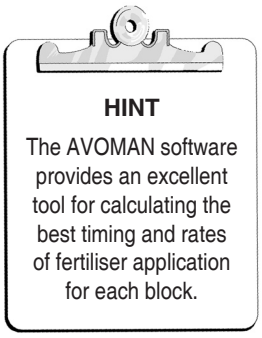
A picture of nitrogen deficiency is in the *Problem Solver,* page 6.

- The main deficiency symptom is pale green to yellow leaves. The change in leaf colour generally begins in older leaves as nitrogen moves to younger leaves. Note that the reverse applies for sulphur deficiency. As nitrogen deficiency becomes more severe, whole shoots will become pale green or yellow. Other symptoms include a lack of vigour, slow growth rates and depressed yields.
- Severe deficiency is rarely seen in eastern Australia where the rate of mineralisation of organic litter is sufficient to maintain enough nitrogen in trees to prevent chronic symptoms from developing. It is more common on the light sandy soils of Western Australia, particularly in spring when trees are flowering heavily.
- Excess nitrogen promotes excessive vegetative shoot growth at the expense of fruiting. This normally results in reduced yield. At toxic levels, it may cause leaf scorch and root death in young trees.

Fertiliser forms

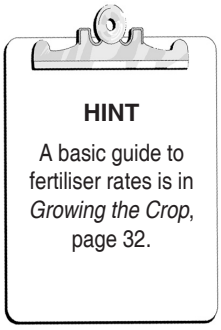
- Urea (46% N).
- Ammonium nitrate – Nitram® (34% N).
- Sulphate of ammonia – Gran-Am® (21% N).
- Potassium nitrate (13% N, 38% K).
- Calcium nitrate (15% N, 18 to 19% Ca).
- Calcium ammonium nitrate – CAN (27N%, 8% Ca).

Management



HINT

The AVOMAN software provides an excellent tool for calculating the best timing and rates of fertiliser application for each block.



HINT

A basic guide to fertiliser rates is in *Growing the Crop*, page 32.

- Must be managed carefully as rate and timing of fertiliser application may significantly affect fruit yield and quality. If too much is applied, the tree is likely to become vegetative at the expense of fruiting. If too much is applied during early fruit development, excessive fruit drop may occur.

Timing of fertiliser application

- Where leaf nitrogen is low, apply one-third of the annual rate at the start of flower bud break in at least two split applications. Restart at the end of summer fruit fall or at the start of February (whichever is earlier). Decrease rates as winter approaches and cease at the end of autumn.
- Where root rot symptoms exist, reduce the total annual rate and apply one-half of the annual rate at the end of flowering in at least two split applications. Restart at the end of summer fruit fall or at the start of February (whichever is earlier). Decrease rates as winter approaches and cease at the end of autumn.
- Where soils are sandy, apply regularly, starting in spring and finishing at the end of autumn. Where soils are very sandy or where significant winter rain causes leaching (for example, Western Australia), apply all year round with lower rates through winter.
- Where growth regulators such as Sunny® are used, add an extra 30% to the nitrogen rate and apply this at the start of flower bud break.
- Where Hass is grown in warm climates and small fruit size is a problem, start application when flower buds begin to swell and continue through until spring flush maturity. We recommend that 30% of the total annual application of nitrogen be applied during late winter–spring. Restart at the end of summer fruit fall or at the start of February (whichever is earlier). Decrease rates as winter approaches and cease at the end of autumn.
- For all other situations, start at the end of summer fruit fall or at the start of February (whichever is earlier). Decrease rates as winter approaches and cease at the end of autumn.

Optimum nutrient levels

- Leaf (dried): 1.6 to 2.0% N (Fuerte and Sharwil); 2.0 to 2.6% N (all other varieties.
- Soil: not reliable as a guide to nitrogen fertiliser use.

Determining rates of fertiliser application

- Factors to consider are:
  – canopy size;
  – leaf nitrogen level;
  – variety (Sharwil and Fuerte require less nitrogen);
  – soil texture (higher rates for lighter soils);
  – root rot status (lower rates for affected trees);
  – degree of leaching (higher rates for higher rainfalls);
  – crop load (higher rates for larger crops);
  – two crops on the tree for part of the year, for example Western Australia, Sunraysia (higher rates);
  – growth regulators used (30% extra nitrogen applied at start of bud break).

Other management issues

- Development of the Phytophthora root rot fungus is favoured by nitrate forms of nitrogen, but suppressed by ammonium forms. Therefore urea and sulphate of ammonia are preferred to potassium nitrate and ammonium nitrate. However, be aware that ammonium forms tend to have a greater acidifying effect than nitrate forms.
- In young non-bearing trees, apply nitrogen in small amounts at regular intervals throughout the year. At least six applications a year are recommended. Be very careful with urea as excessive amounts can kill young trees.

Phosphorus (P)

Function

- Essential for energy metabolism in maintenance and growth.
- Particularly important for root growth and maintaining continued root replacement where Phytophthora root rot is present.

Behaviour in soil and plant

- Only a small proportion of soil phosphorus is generally available for tree uptake. In some soils such as krasnozems and red earths, phosphorus is tightly fixed.
- Relatively immobile in the soil and not readily leached.
- Very mobile in the plant, moving readily in both an upward and downward direction.
- Excessive soil levels may induce iron and zinc deficiencies.

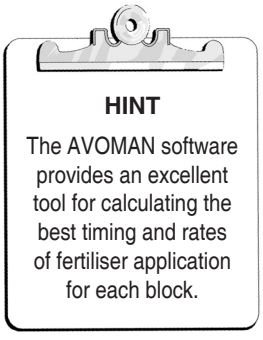
Deficiency/toxicity symptoms

- Deficiency or toxicity symptoms not yet identified in Australia.

Fertiliser forms

- Superphosphate (9% P, 11% S, 20% Ca).
- Triple superphosphate (19% P, 2% S, 18.5% Ca).
- Diammonium phosphate – DAP (18% N, 20% P, 2% S).
- Monoammonium phosphate – MAP (12% N, 22% P, 3% S).
- Rock phosphate (phosphorus content varies according to source; check content before calculating rates).

Management



Timing of fertiliser application

- Because of the immobility of phosphorus in the soil, it is best to determine requirements by soil analysis before planting. Required fertilisers can then be applied well before planting and physically incorporated by deep ripping, ploughing or disc harrowing. Once the orchard is established, monitor by annual leaf analysis and occasional soil analysis.
- As many growers use N:P:K fertiliser blends, phosphorus is generally applied at the same time as nitrogen and potassium. Where phosphorus is applied separately, it is best applied in autumn or winter.

Optimum nutrient levels

- Leaf (dried): 0.08 to 0.25% P.
- Soil: 30 to 60 mg/kg P (bicarb-Colwell).

Determining rates of fertiliser application

- Factors to consider are:
  – canopy size;
  – soil texture (higher rates for heavier soils);
  – leaf phosphorus level;
  – soil phosphorus level (if leaf phosphorus level not available, but only where banding has not been practised);
  – soil type (krasnozems, red earths, Karri loams and podzolic soils require higher rates to compensate for phosphorus fixing).

Other management issues

- Because phosphorus is very immobile in the soil and not subject to leaching, repeated applications will cause phosphorus accumulation in the root zone. This causes two problems: reduced availability of trace elements such as zinc and iron, and excessive phosphorus levels that are almost impossible to reduce. It is very important to regularly monitor soil phosphorus levels by soil analysis, particularly where phosphorus fertilisers are being routinely applied, to ensure that levels are not getting too high.
- Phosphorus-fixing soils (such as krasnozems and red earths) may need small, but regular applications of phosphorus to maintain an available supply of phosphorus to the tree. This problem can be overcome by concentrating the phosphorus fertiliser in a narrow band instead of broadcasting. However, banding can distort future soil phosphorus analyses unless the location of the band is known.

Potassium (K)

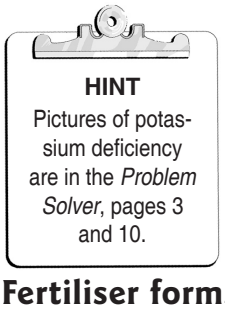
Function

- Several important roles, but the most important appears to be regulation of water balance. It achieves this by influencing water movement and controlling the opening and closing of stomata (water pores on leaves).
- Another important function is the synthesis and movement of starches, sugars and oils. In this role potassium has a direct effect on fruit quality. Excessive levels may reduce the accumulation of calcium in the fruit, reducing quality.

Behaviour in soil and plant

- Very mobile in the soil and readily leached.
- Very mobile in the plant, readily moving in all directions.

Deficiency/toxicity symptoms



HINT
Pictures of potassium deficiency are in the *Problem Solver*, pages 3 and 10.

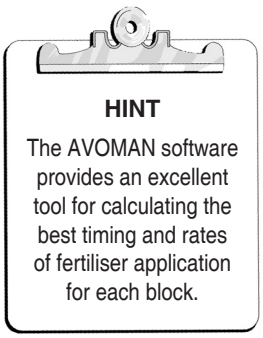
- Deficiency symptoms in the field are generally only observed in trees growing on very light sandy soils. Yellowing begins at the margins of leaves and spreads in towards the veins. Brown spots develop in affected areas. In severe cases, affected leaves show a burnt margin, which is worst towards the tip. However, where potassium levels are low, tree growth and yields can be reduced without visible signs of deficiency.
- Symptoms of toxicity have not been recorded.

Fertiliser forms

- Potassium sulphate – sulphate of potash (41% K, 16.5% S).
- Potassium chloride – muriate of potash (50% K, 50% Cl).
- Potassium nitrate (38% K, 13% N).

Restrictions apply to the use of muriate of potash in avocados because of its high chloride content (see below).

Management



HINT

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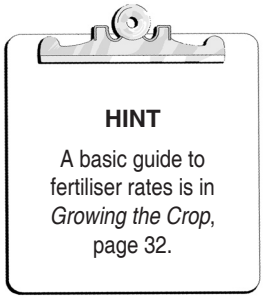


HINT

A basic guide to fertiliser rates is in *Growing the Crop*, page 32.

Timing of fertiliser application

- The main requirement is from summer until late autumn, but where soils are light and leaf levels low, application should start in spring. However, potassium is generally applied at the same time as nitrogen and phosphorus because most growers use N:P:K fertiliser blends. Hence the timing of potassium applications generally mirrors that of nitrogen (see under Nitrogen).

Optimum nutrient levels

- Leaf (dried): 0.75 to 2.0% K.
- Soil: 0.75 to 1.0 meq/100 g K (exchangeable).

Determining rates of fertiliser application

- Factors to consider are:
  – canopy size;
  – leaf potassium level;
  – soil texture (higher rates for lighter soils);
  – root rot status (lower rates for affected trees);
  – degree of leaching (higher rates for higher rainfalls);
  – levels of chloride in leaf, soil and irrigation water (don't use chloride -based fertilisers if high).

Other management issues

- There are situations where potassium chloride (muriate of potash) should NOT be used as the potassium source. Avocados are sensitive to chloride, which can readily cause root and leaf burn. Avoid using muriate of potash when:
  – root rot symptoms are present (chloride will exacerbate the problem);
  – there is already a history of leaf burn as a result of using poor quality irrigation water or slightly saline soil;
  – the chloride level of irrigation water exceeds 80 mg/L;
  – the chloride level of leaves from leaf analysis exceeds 0.15%;
  – the chloride level in soil from soil analysis exceeds 150 mg/kg.

Calcium (Ca)

Function

- Plays an important role in cell division and cell development in leaves, fruit and root tips.
- There is growing evidence that high fruit calcium concentrations suppress the development of fruit diseases such as anthracnose, reduce the potential for chill injury and increase the shelf-life of fruit.

Behaviour in soil and plant

- Relatively immobile in the soil.
- Mobile within the tree in an upwards direction towards the leaf tips with little remobilisation downwards.
- Required in relatively large amounts.

Deficiency/toxicity symptoms

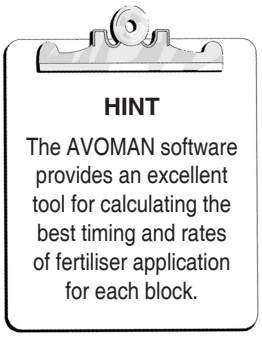
- Deficiency or toxicity symptoms not yet clearly identified in Australia.
- High soil levels may reduce uptake of manganese, zinc, boron, copper and phosphorus.

Fertiliser forms

- Calcium sulphate – gypsum (18 to 20% Ca, 14 to 18% S).
- Calcium nitrate (18 to 19% Ca; 15% N).
- Calcium carbonate – lime (35 to 40% Ca).
- Calcium and magnesium carbonates – dolomite (12 to 15% Ca, 8 to 12.5% Mg).
- Calcium ammonium nitrate – CAN (8% Ca, 27% N).

Management

- Because of its influence on pH, management of calcium involves an analysis of calcium, magnesium and pH levels.



HINT

The AVOMAN software provides an excellent tool for calculating the best timing and rates of fertiliser application for each block.

Timing of fertiliser application

- Because of the immobility of calcium in the soil, it is best to determine calcium levels and pH by soil analysis before planting. Required calcium products can then be applied well before planting and physically incorporated by deep ripping, ploughing or disc harrowing. Once the orchard is established, monitor plant calcium by annual leaf analysis and soil calcium and soil pH by regular soil analysis.
- Calcium fertilisers, along with treatments to correct pH and magnesium levels, are best applied in autumn or early winter.

Optimum nutrient levels

- Leaf (dried): 1.0 to 3.0% Ca.
- Soil: 5.0 to 15.0 meq/100 g Ca (exchangeable).

Determining rates of fertiliser application

- Factors to consider are:
  – canopy size;
  – soil sodium level (if high must be treated by gypsum applications);
  – leaf sodium level (as an indicator that soil sodium may be too high);
  – soil calcium level;
  – leaf calcium level;
  – soil pH.

Other management issues

- The most commonly used products to improve the calcium status of soils are lime, dolomite and gypsum. Care must be taken not to overuse these materials as excessive rates may significantly change the chemical and physical characteristics of the soil and subsequently affect plant growth.
- The choice of calcium product depends on the effect required. Lime is normally used when soil pH and calcium levels are both low. Dolomite is normally used when soil pH, calcium and magnesium levels are all low. Gypsum is normally used when pH is within the desired range, but the soil calcium level is low.

- Increasing the calcium concentration in avocado fruit is not easy. Foliar sprays of calcium products targeting young developing fruit have little or no effect on calcium levels. The use of super-fine gypsum applied several times during the growing season may assist in elevating fruit calcium concentrations, however more research is required to confirm this. As excessive nitrogen levels in trees appear to depress calcium allocation to the fruit, calcium and nitrogen nutrition need to be carefully managed.
- There is recent evidence to suggest that rootstocks may have a significant effect on calcium concentrations in fruit.

Magnesium (Mg)

Function

- An essential component of chlorophyll (the green pigment in leaves) where it helps trap light energy, converting it to chemical energy used to produce sugars.
- Also regulates the uptake of other plant nutrients and is essential for many biochemical cellular functions.

Behaviour in soil and plant

- Relatively mobile in the soil and is absorbed by roots, mainly through passive diffusion.
- High soil concentrations of ammonium, potassium and calcium may compete with magnesium for uptake, leading to magnesium deficiency.
- Very mobile within the tree, moving readily from old leaves to new leaves under deficient conditions.

Deficiency/toxicity symptoms

HINT

A picture of magnesium deficiency is in the *Problem Solver*, page 5.

- Because of the mobility within the plant, deficiency symptoms generally develop in older leaves first. Affected leaves show yellowing, progressing inwards from the margins and tips towards the main veins, leaving a band of dark green along the main veins. Premature defoliation, particularly during flowering, may also occur. Deficiency is most common on acid sandy soils.
- No field symptoms of magnesium toxicity have been recorded. High soil levels may suppress uptake of calcium and potassium.

Fertiliser forms

- Magnesium sulphate – Epsom salts (9.5% Mg).
- Calcium and magnesium carbonates – dolomite (8 to 12.5% Mg, 12 to 15% Ca).
- Magnesium oxide – Granomag® (54% Mg).

Management

HINT

The AVOMAN software provides an excellent tool for calculating the best timing and rates of fertiliser application for each block.

- Similar to calcium, in that management of magnesium involves an analysis of calcium, magnesium and pH levels.

Optimum nutrient levels

- Leaf (dried): 0.25 to 0.8% Mg.
- Soil: 1.6 to 3.0 meq/100 g Mg (exchangeable).

Timing of fertiliser application

- Like calcium, it is best to determine magnesium levels and pH by soil analysis before planting. Required fertilisers can then be applied well

before planting and physically incorporated by deep ripping, ploughing or disc harrowing. Once the orchard is established, monitor magnesium, calcium and soil pH by annual leaf and soil analysis.

- Magnesium fertilisers, along with treatments to correct pH and calcium levels, are best applied in autumn or early winter.

Determining rates of fertiliser application

- Factors to consider are:
  – canopy size;
  – soil magnesium level;
  – leaf magnesium level;
  – soil pH.

Other management issues

- The choice of magnesium product depends on the soil magnesium level, soil pH and soil calcium level. As excessive application of magnesium may suppress the uptake of calcium and potassium, it is important to consider the balance of magnesium with these elements (referred to as the cation exchange capacity) when attempting to correct magnesium soil deficiencies. Dolomite is normally used when soil pH, calcium and magnesium levels are all low. Granomag® is normally used when pH is within the desired range, but the soil magnesium level is low.

Sulphur (S)

Function

- An important component in proteins and chlorophyll.

Behaviour in soil and plant

- Relatively mobile in the soil.
- There is little impact from other nutrients on the uptake and movement of sulphur absorbed by roots.
- Movement in the tree is mainly upwards. Once incorporated in proteins, it cannot be remobilised for use in other parts of the plant in times of deficiency.

Deficiency/toxicity symptoms

- Sulphur deficiency stunts plant growth. As it is required for chlorophyll production, a deficiency results in yellow leaves. However, as sulphur is not remobilised from older tissues, the yellowing develops in young expanding leaves while the older leaves remain dark green. This is an opposite effect to nitrogen deficiency. There have been no field reports of sulphur deficiency in Australian avocado orchards.

Fertiliser forms

- Sulphate of ammonia – Gran-Am® (24% S).
- Superphosphate (11% S).
- Single superphosphate with sulphur (26.1% S).
- Gypsum (14 to 18% S).
- Elemental sulphur (98 to 100% S).

Management

- There are no specific management strategies for sulphur fertilising in avocados. Under normal circumstances, fertilisers commonly used

(superphosphate, sulphate of ammonia, sulphate of potash and gypsum) generally contain enough sulphur to meet tree requirements.

Optimum nutrient levels

- Leaf (dried): 0.2 to 0.6% S.
- Soil: more than 20 mg/kg S (Phos. extr.).

Boron (B)

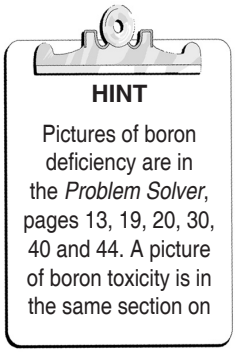
Function

- An important role in cell division and cell growth. Important in areas of the plant where cell development is significant (for example, flowers, fruit, shoot tips and root tips).
- Important role in root health.
- Avocados require significantly higher amounts of boron than other crop species. However, the range between boron deficiency and toxicity is narrow, so careful management is required.

Behaviour in soil and plant

- Very mobile in the soil and is easily leached.
- Not very mobile within the plant, with any movement occurring in an upwards direction with little remobilisation downwards. Consequently, in most Australian growing environments, trees require a constant supply of boron throughout the year from small, but frequent applications.

Deficiency/toxicity symptoms

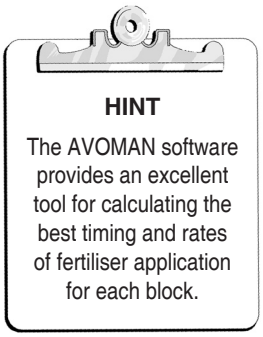


- Boron deficiency retards normal root growth, leading to tree decline. Leaf symptoms include yellowing and a shot-hole effect, particularly in the spring flush. Shoot symptoms include swelling of the nodes, corky lesions, and horizontal rather than vertical growth. In severe cases, lesions may develop on branches and major limbs. In Hass, limbs may dieback. Under prolonged deficiency conditions, trees will be stunted with prostrate growth, as a result of the loss of apical dominance. Trees will flower earlier than normal, usually with severe leaf fall. Affected fruit are misshapen, with possible corky lesions. Under cool storage, mature fruit may show browning of the seed cavity. Deficiency symptoms are most strongly expressed during spring, the most active growth period of the year, when the greatest demand is placed on the feeder root system that has been depleted during flowering.
- Excessive boron can be toxic. Toxicity symptoms are generally first seen in older leaves. Affected leaves develop a continuous marginal browning, which starts at the tips of older leaves, spreads to the sides, and ultimately develops around the entire leaf margin. The browning has a sharply defined dark brown border. A 1 to 2 mm wide band of light yellow tissue develops on the inner edge of the dark brown border. The affected leaf edges begin to curl downwards and small dead spots begin to form further into the interveinal area. Leaves and fruit may be shed if the toxicity becomes chronic. Affected fruit ripen with a pink discolouration of the water-conducting tissues in the flesh. If toxicity is suspected, stop further applications of boron and seek professional advice. Toxicity is more likely on lighter soils.

Fertiliser forms

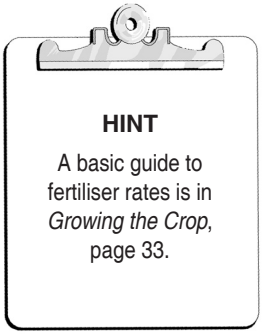
- Borax (11% B).
- Solubor (22% B).
- Boric acid (17% B).

Management



HINT

The AVOMAN software provides an excellent tool for calculating the best timing and rates of fertiliser application for each block.



HINT

A basic guide to fertiliser rates is in *Growing the Crop*, page 33.

Timing of fertiliser application

- Start soil applications four weeks before flower bud break and continue at regular intervals throughout the year. These intervals can be weekly on very sandy soils or up to every two months in clay soils.
- If the autumn leaf boron level is less than 30 ppm, apply one foliar spray application three weeks after flower bud break. Use Solubor at a rate of 1g/L. Foliar applications at other times are NOT recommended. Foliar sprays are **not** a substitute for the soil applications.

Optimum nutrient levels

- Leaf (dried): 40 to 60 ppm B.
- Soil: 3 to 12 mg/kg B (clay soils); 2 to 8 mg/kg B (clay loam soils); 0.75 to 3.0 mg/kg B (loam soils); 0.25 to 1.0 mg/kg B (sandy loam and sandy soils) (hot calcium chloride).

Determining rates of fertiliser application

- Factors to consider are:
  - canopy size;
  - soil texture (light soils require much lower rates than heavier soils);
  - excessive levels of soil boron (considered in case of potential toxicity whether leaf boron levels are available or not);
  - leaf boron level;
  - soil boron level (if leaf boron level is not available);
  - root rot status (lower rates for affected trees);
  - degree of leaching (higher rates for high rainfall);
  - variety (Sharwil and Wurtz require higher rates);
  - rootstock (Mexican rootstocks require higher rates);
  - boron content of irrigation water (safety check in case of high boron levels in the water; high levels have been recorded in Sunraysia–Riverland and parts of Western Australia).

Other management issues

- Boron is deficient in most avocado soils in Australia, particularly in the light soils of Western Australia and the high rainfall areas of subtropical eastern Australia.
- To avoid toxicity, always ensure that the boron product is spread evenly. Alternatively, use soluble forms (Solubor, boric acid) and apply by fertigation.
- If an application is due and the orchard has received very little rain or irrigation since the last application, postpone the application until substantial rain is received or irrigation applied.
- In areas with high boron levels in irrigation water, monitor tree boron levels by annual leaf and soil analysis to avoid toxicity.

Zinc (Zn)

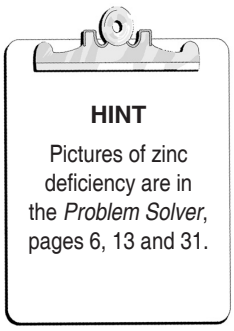
Function

- An essential role in the production of enzymes and plant hormones. Hence growth is distorted when deficiency occurs.
- Has a regulatory role in the uptake of water.
- Necessary for normal chlorophyll formation.

Behaviour in soil and plant

- Not very mobile in the soil. It has been shown that mycorrhiza assist with the root uptake of zinc.
- Not very mobile in the tree. Tends to accumulate in roots.

Deficiency/toxicity symptoms



HINT

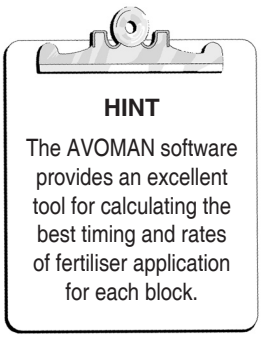
Pictures of zinc deficiency are in the *Problem Solver*, pages 6, 13 and 31.

- Zinc deficiency is common in Australian orchards. Edranol is the most sensitive variety and can be used as an indicator tree. Affected leaves show uneven blotchy yellowing between the veins. With a mild deficiency, leaf size is only marginally reduced and leaf distortion is minimal, but the distance between the leaves on the shoot is shortened, producing a 'feather duster' appearance. A more severe deficiency causes significant leaf distortion and reduction in leaf size, with the youngest leaves at the end of shoots becoming yellow, small and distorted. Fruit from zinc-deficient trees tend to be smaller and rounder than fruit from normal trees of the same variety.
- Zinc toxicity has not been recorded.

Fertiliser forms

- Zinc sulphate heptahydrate (23% Zn).
- Zinc sulphate monohydrate (36% Zn).
- Zinc oxide (80% Zn).

Management



HINT

The AVOMAN software provides an excellent tool for calculating the best timing and rates of fertiliser application for each block.

Timing of fertiliser application

- Since zinc is relatively immobile in the soil, it is best to correct any deficiency before planting. Zinc-based fertilisers can be spread and physically incorporated through the soil profile by deep ripping, ploughing or disc harrowing. Once the orchard is established, monitor zinc levels by annual leaf and soil analysis.
- Where zinc is required in established orchards, apply to the soil at the dripline of the tree in a 30 cm wide band around the canopy. Alternatively, run a straight band or ribbon under the dripline or within the irrigated root zone down both sides of the row. With either option, the band or ribbon must be within the wetted area of the irrigation system. Zinc can be applied using fertigation, but it is not recommended. However, if fertigation is used, increase rates by 50%.
- For sandy soils such as those in south-west Western Australia, use zinc sulphate heptahydrate and physically incorporate the band or ribbon into the soil.
- Zinc foliar sprays are **not** recommended as the effect is short-lived and it interferes with subsequent leaf analyses through contamination of the leaf samples.
- Apply soil applications in the spring at flower bud break.

Optimum nutrient levels

- Leaf (dried): 40 to 80 ppm Zn.
- Soil: 5 to 10 mg/kg Zn (DTPA).

Determining rates of fertiliser application

- Factors to consider are:
  - canopy size;
  - leaf zinc level (but only if foliar applications have not been applied in the previous 12 months);
  - soil zinc level (if leaf zinc level is not available and zinc has not been banded previously);
  - soil pH (zinc availability is significantly reduced by high pH, so if pH is high, the rate needs to be significantly increased);
  - soil texture (higher rates in heavier soils);
  - soil phosphorus level (zinc availability is reduced by high soil phosphorus levels);
  - soil organic matter (zinc availability improved by moderate organic matter levels);
  - whether avocado roots are in mulch (zinc availability improved);
  - if obvious deficiency symptoms exist (use if leaf and soil levels are not available or are invalid because of zinc application history).

HINT

Basic fertiliser rates are contained in *Growing the crop* Section 3 page 32.

Other management issues

- Zinc is deficient in most Australian soils where avocados are grown. Adjustment of soil levels is generally necessary.
- Zinc availability is reduced by high soil phosphorus concentrations and high pH (higher than 7.0). Before zinc is applied, allow two months to elapse after a heavy application of phosphorus (more than 10 g phosphorus/sq. m). This is especially necessary for sandy to sandy loam soils.

Iron (Fe)

Function

- Critical function in the production of chlorophyll (the green pigment in leaves).

Behaviour in soil and plant

- Generally an abundant element in the soil; relatively mobile.
- Not very mobile within the tree.
- Uptake can be suppressed by high pH, high levels of soil phosphorus and high levels of soil manganese.

Deficiency/toxicity symptoms

- Iron deficiency shows on young leaves as an interveinal yellowing or whitening with the veins remaining dark green. The symptoms are generally confined to young leaves of the summer flush.
- Iron deficiency is typical in the following situations:
  - calcareous soils (characterised by high calcium levels);
  - soils with a high pH;
  - soils with very high levels of manganese;
  - soils with very high levels of phosphorus;

HINT

Pictures of iron deficiency are in the *Problem Solver*, page 7.

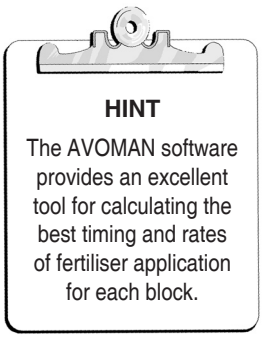
– as a consequence of poor soil aeration (poor drainage, compacted soils, excessive irrigation).

- There are no records of iron toxicity under field conditions.

Fertiliser forms

- Iron sulphate (23% Fe). For use in all situations.
- Iron chelate or iron EDDHA (5 to 15% Fe, for example Sequestrene 138®. For use in soils with a pH greater than 7.0.

Management



HINT

The AVOMAN software provides an excellent tool for calculating the best timing and rates of fertiliser application for each block.

Timing of fertiliser application

- Timing is not critical, but recommended in spring at flower bud break.

Optimum nutrient levels

- Leaf (dried): not considered reliable, but 50 to 200 ppm iron is commonly used as an optimum range.
- Soil: 4 to 20 mg/kg Fe (DTPA).

Determining rates of fertiliser application

- Factors to consider are:
  – canopy size;
  – soil iron level (leaf levels are not reliable);
  – soil pH (if it is very high, iron chelate should be used);
  – soil calcium level (if it is very high, iron chelate should be used);
  – soil phosphorus level (high phosphorus in the soil will reduce iron availability);
  – soil manganese level (at low soil pH, high manganese levels reduce iron availability).

Other management issues

- Iron is not normally a problem in the acid soils of most avocado growing areas. However, in calcareous soils, iron is one of the more difficult trace elements to correct. In these conditions, the use of certain West Indian rootstocks and the application of iron chelate as a collar drench have been successful.
- If the pH and/or soil calcium level is very high, applications of iron sulphate are unlikely to be effective. In these situations, use iron chelate instead. The recommended product is iron chelate (or iron EDDHA available as Sequestrene 138®). The rate is 8 g/sq. m of canopy area per year, banded or fertigated at the start of flower bud break.

Manganese (Mn)

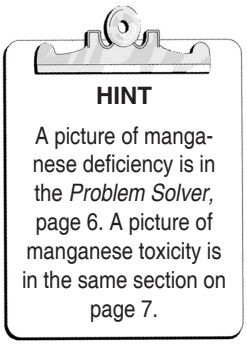
Function

- Important for photosynthesis.

Behaviour in soil and plant

- Relatively mobile in the soil.
- Once entering the tree, manganese is relatively immobile.
- Manganese availability is greatly reduced when the soil pH exceeds 7.0.

Deficiency/toxicity symptoms



HINT

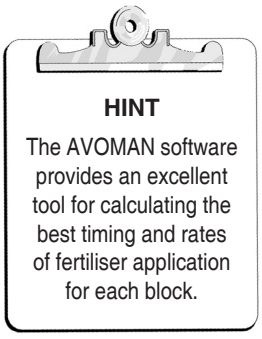
A picture of manganese deficiency is in the *Problem Solver,* page 6. A picture of manganese toxicity is in the same section on page 7.

- Manganese deficiency is not common, but may occur in very coarse sandy soils. Symptoms are an interveinal chlorosis, similar to that of zinc and magnesium deficiencies.
- Manganese toxicity is a more common and serious problem. Toxicity may be present and affecting production before leaf symptoms are obvious (leaf symptoms are generally not seen until levels exceed 1500 mg/kg). Leaves develop small dead spots throughout the interveinal tissue. An indirect symptom of manganese toxicity is iron deficiency. This is most commonly found where manganese oxide lumps ('concretions') are present in the soil. High temperatures and free soil water during summer increase the availability of manganese, which in turn depresses the uptake of iron. Leaves produced on new shoots during this time of the year are typically iron deficient (pale yellow to white).

Fertiliser forms

- Manganese sulphate (33% Mn).

Management



HINT

The AVOMAN software provides an excellent tool for calculating the best timing and rates of fertiliser application for each block.

Timing of fertiliser application

- Timing not critical, but recommended in spring at flower bud break. In most soils, manganese deficiency can be easily remedied by one or two applications of manganese sulphate. However, in very coarse sandy soils, regular applications may be required.

Optimum nutrient levels

- Leaf (dried): 30 to 500 ppm Mn.
- Soil: 6 to 40 mg/kg Mn (DTPA).

Determining rates of fertiliser application

- Factors to consider are:
  – canopy size;
  – soil manganese level (used in preference to leaf level in this case);
  – leaf manganese level;
  – soil texture;
  – soil pH;
  – organic matter level.

Other management issues

- Where the soil manganese level is over 40 ppm, manganese toxicity is likely. In this situation, the target soil pH should be 6.5 (1:5 soil water) instead of 5.5.
- Where manganese-induced iron deficiency is a problem, the effect can be reduced by increasing the soil pH to about 6.5 (1:5 soil water) and by improving soil drainage.

Copper (Cu)

Function

- Involved in the transfer of energy in various tree processes such as photosynthesis.
- Also important in the production of lignin, which provides strength to the growth of lateral branches.

Behaviour in soil and plant

- One of the least mobile elements in the soil and not easily leached.
- Not readily mobile within the tree, though if present in sufficient quantities it will be translocated from older to younger leaves.

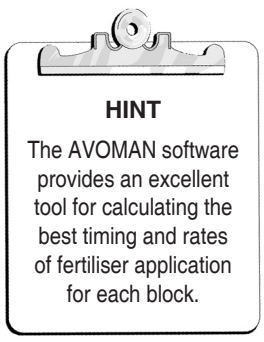
Deficiency/toxicity symptoms

- Copper deficiency has not been recorded in eastern Australia where regular copper fungicide sprays are used. However, deficiency symptoms have been recorded on the very sandy soils of Western Australia.
- Copper deficiency shows as a whitening of leaf tips and a distortion of leaf growth. The symptoms are more common in younger leaves.
- Copper deficiency can be induced by:
  - high nitrogen applications;
  - high soil phosphorus levels;
  - high soil zinc levels;
  - high soil calcium levels.
- While copper toxicity has not been specifically recorded in avocados in Australia, leaf levels over 300 ppm are considered excessive.

Fertiliser forms

- Bluestone – copper sulphate pentahydrate (25% Cu).
- Copper is also available in several fungicides including copper oxychloride and copper hydroxide. If copper fungicides are regularly used for disease control, then there is generally no need to use copper fertilisers.

Management



HINT

The AVOMAN software provides an excellent tool for calculating the best timing and rates of fertiliser application for each block.

Timing of fertiliser application

- In humid climates where anthracnose disease is a problem, any deficiencies are indirectly addressed by the regular application of copper fungicide sprays. Elsewhere, deficiency is relatively easily remedied by soil application of copper sulphate. Timing is not critical, but application during spring at flower bud break is recommended.

Optimum nutrient levels

- Leaf (dried): 5 to 15 ppm Cu.
- Soil: 0.3 to 10 mg/kg Cu (DTPA).

Determining rates of fertiliser application

- Factors to consider are:
  - canopy size;
  - frequency of copper fungicide applications (none required if these are frequently applied);
  - leaf copper level (only if no copper fungicides are used);
  - soil copper level;

– soil texture (higher rates for lighter soil types);
– soil organic matter level (higher levels reduce the availability of copper);
– soil pH (high pH reduces the availability of copper).

Other management issues

- As copper is relatively immobile in the soil, uptake depends on good root growth. Root rot control is therefore important for copper uptake.
- Do not use copper sulphate as a foliar spray, especially when flowers are present, as this can damage the plant.
- There is considerable debate about copper residues from repeated copper fungicide sprays washing into the soil and causing copper toxicity. Concern is heightened because copper is relatively immobile in the soil and will tend to accumulate over time. Although a direct effect on production is yet to be demonstrated, research has shown that high copper levels significantly reduce populations of soil microbes.

Important components of the fertiliser program

Once you have the essential knowledge of soil pH and the various individual nutrients, a fertiliser program tailored to your orchard can be put in place. The essential components are:

1. Pre-plant soil analysis and adjustment of nutrients, particularly the insoluble ones.
2. Regular application of growth-promoting nutrients, particularly nitrogen, during the young tree growth phase.
3. Once trees begin bearing, management that takes into account:
   - annual leaf and soil analysis;
   - correct timing of fertiliser application (recording growth cycles; choosing appropriate intervals between applications);
   - selecting appropriate fertilisers;
   - correct placement of fertilisers;
   - calculation of appropriate rates of fertiliser.

Pre-plant soil analysis and adjustment of nutrients

more info
Pre-plant soil analysis
Section 3 page 11

Do a pre-plant soil analysis to enable nutrients to be adjusted to their optimum levels throughout the intended root zone before planting. This is particularly important for the adjustment of insoluble nutrients such as phosphorus, calcium, zinc and copper, which are difficult to adjust once the trees are in the ground.

For details, follow the recommendations in *Growing the Crop*.

Young non-bearing trees

more info
Fertilising young trees
Section 3 page 18

During the first couple of years, the aim is to quickly grow a strong healthy tree structure that will bear well in future years. Apply small amounts of fertiliser at regular intervals to maintain active tree growth.

For details, follow the recommendations in *Growing the Crop*.

Organic fertilisers can be used at this stage. These not only supply small amounts of nutrient, but also improve the microbial activity of the soil, an important feature in suppressing Phytophthora root rot disease.

Bearing trees

Annual leaf and soil analysis

An annual leaf and soil analysis allows the fertiliser program to be fine-tuned to each variety, block and soil type for each year's conditions. It ensures that enough fertiliser is applied to maintain optimum fruit production and quality, without contributing to excessive nutrient levels in the soil and groundwater.

Leaf and soil sampling
Section 3 page 30 – 31

For instructions on how to undertake leaf and soil analysis, follow the recommendations in *Growing the Crop*.

Correct timing of fertiliser application

Fertiliser application is timed to various stages of the growth cycle to achieve maximum impact. The most appropriate stages for each nutrient are in 'Understanding the individual nutrients', this section, page 78. A collective summary of timings is also in the *Crop Production Handy Guide*.

AVOMAN recording system
Section 4 page 34

As well as timing, the interval between successive applications needs to be carefully managed. This is governed by:

- **Soil type**. Short intervals are appropriate for light sandy soils while longer intervals can be used for heavier clay soils. Light sandy soils with low cation exchange capacities can hold only small amounts of nutrient in the root zone. Frequent light doses of nutrient are required to maintain supply to the tree. On the other hand, heavier clay soils with high cation exchange capacities can hold more nutrient and therefore do not have to be replenished as often.
- **The nutrient being applied**. Nitrogen, potassium and boron are easily leached so need to be applied regularly. Most of the other nutrients only need to be applied when leaf or soil analysis shows availability is low.
- **Expected rainfall**. In high rainfall areas, frequent light doses are preferred as this reduces losses from leaching.
- **Fertigation compared to solid fertiliser application**. Where fertigation is being used, shorter intervals with smaller doses can be used. This is of great advantage in sandy soils where nitrogen, for example, can be applied in small doses each week.

Selecting appropriate fertilisers

In avocados, fertiliser selection involves consideration of several issues. Here are the main ones.

- **Manufactured or organic fertilisers**. While organic fertilisers have certain desirable features, manufactured fertilisers are preferred as the main nutrient source for bearing trees because they produce a more predictable response. A problem with organic fertilisers is that the release of nutrients such as nitrogen is unpredictable and may occur at the wrong stage of the growth cycle. Note that organic fertilisers are highly recommended during young tree establishment and growth.
- **Straight or mixed fertilisers.** Straight fertilisers are preferred as they enable application rates to be adjusted individually for each nutrient.

They are also generally cheaper per unit of nutrient. Mixed fertilisers are more convenient to use, but may cause a nutrient imbalance by oversupplying or undersupplying particular nutrients.

- **Foliar fertilisers.** Foliar nutrient sprays are generally not recommended in avocados, as the waxy shiny leaves prevent significant nutrient uptake. The one exception is a foliar spray of boron before flowering when leaf boron levels are below 30 ppm. In this case, the uptake is mostly by the developing flower parts, not the leaves.
- **Impact on soil acidity.** If your soil is acid, choose the least acidifying fertiliser available. The acidifying effect of common fertilisers is shown in Table 11.

Table 11. *Acidifying effect of common fertilisers*

Fertiliser	Acidifying effect 1 = highly acidifying; 5 = non-acidifying
MAP	1
Sulphate of ammonia	2
DAP	2.5
Urea	3
Nitram® (ammonium nitrate)	3.5
Superphosphate	4
Muriate of potash (potassium chloride)	5

Note: Most mixed fertilisers are based on sulphate of ammonia and therefore acidify the soil.

- **Impact on soil salinity**. If salinity is a problem, choose fertilisers with a low salt index. The salt index of some common fertilisers is shown in Table 12.

Table 12. *Salt index of common fertilisers (for comparison, common salt has a salt index of 154)*

Fertiliser	Salt index
Muriate of potash	114
Nitram® (ammonium nitrate)	105
Urea	75
Potassium nitrate	74
Sulphate of ammonia	69
Sulphate of potash	46
DAP	34
MAP	30
Gypsum	8
Superphosphate	8
Lime	5
Dolomite	1

- **Impact on Phytophthora root rot**. Development of the Phytophthora root rot fungus in the soil is favoured by nitrate forms of nitrogen, but suppressed by ammonium forms. Urea and sulphate of ammonia are preferred to potassium nitrate and ammonium nitrate.
- **Solubility**. Where fertigation is used to apply nutrients, the fertilisers must be highly soluble to avoid pump damage and pipe blockages. See Table 13 for a list of fertilisers suitable for fertigation.

Fertiliser placement

In mature trees, roots generally extend into the middle of the interrow. Therefore the whole orchard should receive some fertiliser. However, set up the fertiliser spreader to place most of the fertiliser under the tree canopy.

The exceptions to this rule are zinc and in some soil types, phosphorus fertilisers. These require banding. For details, see the management notes for zinc and phosphorus in 'Understanding the individual nutrients', this section page 78.

Calculation of appropriate rates of fertiliser

Calculating the appropriate rate of fertiliser to apply is a complex process involving an analysis of leaf and soil test results and a range of orchard and site condition factors. The factors to consider for each nutrient are shown in 'Understanding the individual nutrients', this section page 78.

AVOMAN recording system
This section 4 page 34

The AVOMAN software provides an excellent means of considering all issues and calculating fertiliser rates.

Fertigation

Fertigation (application of fertiliser through the irrigation water) is recommended and has many advantages over the manual application of solid fertilisers. It uses less labour, there is more efficient nutrient uptake and fertilisers can be applied more regularly and conveniently. With efficient fertigation, annual rates of nitrogen and potassium can generally be reduced by about 25%.

With fertigation, fertiliser is dissolved in water in a drum or tank and sucked or injected through the watering system. The preferred equipment is a venturi injection pump or a pressure differential system. Fertilisers used must be highly soluble to avoid pump damage and pipe blockages. Mixtures of fertiliser must also be compatible to avoid the development of precipitates, which can block sprinklers and also cause root damage. Other major requirements are good filtration and a uniform irrigation system that delivers similar amounts of water to all trees in the orchard.

In planning a fertigation system, pay particular attention to the area of ground wetted by the irrigation system. If it is relatively small (20% or less of the orchard floor), fertiliser application may be too concentrated and affect root health. This is particularly important for potentially toxic nutrients such as boron. If the wetted area is too large (80% or more of the orchard floor), much of the fertiliser may be out of reach of the roots, particularly in the case of younger trees.

The most suitable fertilisers for fertigation are listed in Table 13.

Several suitable commercial soluble fertilisers that supply a range of nutrients are also available. These include Flowfeed® and Liquifert®.

You can fertigate every time you water if you wish, but once a fortnight or a month is sufficient and most practical. In very sandy soils, weekly fertigation is suggested.

Before you start fertigating, get a water testing laboratory to fully analyse your irrigation water. Make sure an iron test is included. Seek professional advice from an experienced irrigation designer on planning and operating the system.

It is also important to regularly monitor soil pH in both the wetted area and outside of it, as most fertilisers acidify the soil. Sample both the surface soil (0 to 15 cm) and deeper soil (up to 30 cm). Applications of micro-fine lime, which can be applied through the fertigation system as a suspension (provided there is sufficient agitation), help to keep soil pH within the desired range. Also, nitrate-based fertilisers such as potassium nitrate and calcium nitrate have a lower acidification effect.

Table 13. *Soluble fertilisers for fertigation*

Fertiliser	Main nutrient supplied
Urea	Nitrogen
Calcium nitrate	Nitrogen, calcium
Potassium nitrate	Potassium, nitrogen
Potassium sulphate (K spray)	Potassium
MAP (technical grade)	Phosphorus, nitrogen
Magnesium sulphate (Epsom salts)	Magnesium
Solubor	Boron
Boric acid	Boron
Zinc sulphate heptahydrate	Zinc
Iron sulphate	Iron
Iron chelate	Iron
Manganese sulphate	Manganese
Copper sulphate pentahydrate	Copper

Managing crop production: Irrigation management

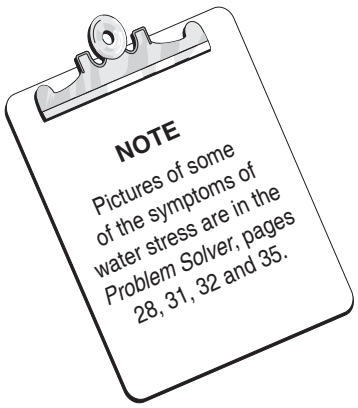
For most environments where avocados are grown in Australia, irrigation is essential. Avocado trees have a relatively shallow root system with few root hairs, making water uptake inefficient. Water stress at critical times in the development of the crop can dramatically affect fruit yield, size and quality. An efficient watering system, and its effective management through moisture monitoring and irrigation scheduling, is most important in maximising profitability.

The importance of good irrigation management

The avocado tree is finely balanced in how it reacts to water management.

On the one hand, too **little** water causes:

- Reduction in yield of up to half that of well watered trees as a result of reduced fruit number and size.
- Flowering earlier than normal at a time when temperatures are still cool, causing poor fruit set and the production of 'cocktail' fruit (cukes).
- Increased fruit drop in spring and early summer.
- Premature death of the seed coat causing a reduction in potential fruit size, particularly if the tree is stressed in the first six to eight weeks after fruit set.
- 'Ringneck' (browning of the fruit stalk), resulting in fruit that are smaller and of poor quality. Fruit skin near the stem end may also crack.
- Poor fruit shape and internal quality because of a reduced uptake of boron and calcium.
- An increase in stem-end rot disease in fruit.
- More rapid ripening of fruit.



Recent research has also shown that the effects of inadequate moisture are not temporary. Evidence indicates that moisture stress leads to restrictions in the tree's water-conducting tissues. This appears be a survival mechanism to conserve moisture. However, when adequate moisture supply is restored, these restrictions remain, reducing the water efficiency of the tree for life.

On the other hand, too **much** water causes equally significant effects:

- Reduction in tree vigour through reduced soil aeration.
- If the roots are waterlogged for more than 48 hours, potential death of the tree.

- Increased incidence and severity of Phytophthora root rot.
- Increased risk of nutrient imbalances. Levels of some available nutrients will become toxic under waterlogged conditions.
- Increased leaching of nutrients from the root zone, which wastes fertiliser and pollutes the groundwater.

Factors affecting water demand and availability

Tree condition and size

Trees with sparse foliage, such as those affected by Phytophthora root rot, will use less water than trees with dense foliage. Small trees will also use less water than large ones.

Stage in the growth cycle

Water need is high from flowering until fruit have reached full size. Critical periods are at flowering and fruit set, during early fruit growth and when fruit are approaching maturity. Note these important points:

- Trees require significantly more water during flowering because the evaporative surface of the tree increases by up to 90%. Severe water stress at this time may result in a very small crop or no crop at all.
- Water stress during early fruit growth may affect ultimate fruit size and quality, as well as yield. The influence of calcium on fruit quality appears during this early stage and its availability is very dependent on a continuous water flow.
- Water stress increases fruit drop at the small and large fruit drop events.
- Water stress during the peak demand periods in summer may cause the 'ringneck' problem, particularly during hot, dry conditions.

Climate and weather conditions

The amount of water required by the tree is directly related to the net evaporation rate. Evaporation is highest when humidity is low and conditions are hot and windy. Trees adjust to these conditions by closing their stomata (water pores) to reduce moisture loss. However, when this happens, photosynthesis is reduced and potential productivity is affected.

Root distribution

About 80% of the avocado white feeder root system is found in the top 45 cm of soil. Only a small percentage is at depths greater than 50 cm. This means the biggest water demand will be at relatively shallow depths, which emphasises the need to keep the upper root zone moist at all times through irrigation and mulching.

Soil features

Surface condition. An open loose soil surface allows better water penetration from rainfall and irrigation. Compare this with a hard-baked, compacted surface where much of the water received will run off and not penetrate. An open loose soil surface is best achieved through mulching.

Texture. Soil texture affects water storage capacity. Well-structured clay soils will store more water than coarse sands, and sandy soils will need to

be irrigated more frequently than clays. However, there is also the risk of over-irrigating sandy soils and wasting water and nutrients.

Soil texture also affects water infiltration. Coarser textured sands will allow rain or irrigation to infiltrate at a faster rate than finer textured clays. On heavy clay soils, more water will generally run off during heavy rain. Well-structured volcanic krasnozem soils (clay loams) have infiltration rates more like sandy loams. Infiltration rates (usually measured in mm/hour) need to be taken into account when designing irrigation systems.

Depth. The greater the depth of well-drained soil, the greater is the water reservoir that the tree can draw from.

Organic matter. Soils with higher organic matter levels can store more water.

Mounds

Mounds are sometimes constructed where the depth of well-drained soil is marginally less than what is required for good soil drainage. However, mounds tend to dry out faster than flat ground and may require up to 20% extra water. Carefully monitor soil moisture in these situations.

Water quality

Avocados are sensitive to the quality of irrigation water. Water salinity or conductivity should be less than 0.6 deciSiemens per metre (dS/m) and chloride content less than 80 milligrams per litre (mg/L). Test all new irrigation sources before use and test all existing sources regularly. In the Sunraysia–Riverland and Carnarvon area in Western Australia where water quality may be marginal, growers should also seek advice on appropriate rootstocks such as West Indian types, which are more tolerant of saline conditions. Also, in these situations, heavier irrigations are required from time to time to flush accumulated salts out of the root zone.

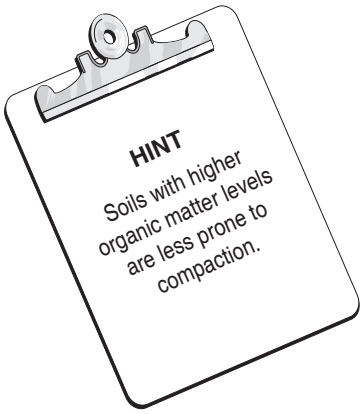
Mulch

Mulching has a significant beneficial effect on water management, as well as assisting with the management of root rot, weed control and nutrient uptake. Mulch works mainly by insulating the soil from the sun and wind. Evaporation from the soil is reduced and a more equitable soil temperature is achieved. As a result, soil microflora increase in number, organic matter builds up and a more open soil structure develops. Higher organic matter levels and a more open soil structure allow water to penetrate more easily before running off. The soil can also store more moisture, which is particularly important during the critical periods of flowering, fruit set and early fruit growth. Substantial savings in irrigation water can be achieved by mulching.

Compaction

Compacted soil reduces water infiltration, stores less water, and is harder for roots to penetrate. Some interrow compaction is inevitable from machinery traffic in orchards. The problem can be minimised in the following ways.

- Maintain an interrow plant cover on the ground. Cover plants help to keep the soil structure open through root activity and reduce surface soil erosion. The key to healthy cover plants is to allow sufficient light to reach the orchard floor. This is achieved by good canopy management.



- Avoid unnecessary use of machinery in the orchard. This involves pest monitoring to avoid unnecessary sprays, greater use of fertigation to minimise machinery application of fertilisers and longer intervals between slashing.
- Avoid use of machinery immediately after rain, as this often seals the soil surface.
- Limit the surface area of the orchard subjected to compaction by using similar wheel track positions when travelling down the interrow.
- Use a soil renovator about once a year. Several types are available. They all work by opening up the soil surface without significantly damaging root systems or the interrow plant cover.

Windbreaks

Windbreaks prevent excessive water loss from foliage under windy conditions and are recommended in all orchards. When installing irrigation, cater for the windbreak trees as well as the orchard trees. This helps them to grow faster and provide earlier protection.

Variability in the orchard

Within every orchard, there will be significant variability in soil texture, soil depth and other factors affecting water availability. It is important to cater for this in designing and operating an irrigation system. This allows trees on different soil types to be irrigated separately. We recommend that growers develop a soil map of their orchard block. This is a general map of the property showing the main features and block boundaries, on which you record soil texture and depth from several inspection holes on a grid pattern across the block.

Full details on soil inspection and the development of a soil map are contained in 'Selecting the right site', this section page 5.

For a small property, the holes can be dug by hand with a soil auger or posthole digger. For a larger property, hire a contractor with a motorised truck-mounted auger. Contractors providing this service are generally listed in the local Yellow Pages directory under 'Soil testing and investigation'.

A good irrigation system

The requirements for efficient irrigation are:

- a reliable supply of good quality water;
- an irrigation system capable of delivering the requirements of the tree evenly;
- an effective means of monitoring water requirements so the required amount of water can be applied at the right time.

This subsection covers the irrigation system while the next discusses monitoring systems.

***Figure 23**. An under-tree minisprinkler*

In designing and building an effective irrigation system, there is no substitute for experience. We recommend that you use a qualified irrigation designer to prepare an irrigation design plan.

The basic requirements are:

- **Under-tree minisprinklers** are the recommended system (Figure 23), given the tree's shallow feeder root system and its susceptibility to desiccation. Under-tree minisprinklers provide the best option for keeping all of the roots hydrated.

- **Irrigate all of the under-canopy root zone**. Two minisprinklers will be needed, one on either side of the trunk, by the time the tree reaches maturity. Some growers irrigate all of the **total ground area** (interrow as well as under-canopy) to grow mulch material between the rows for later placement under the canopy. However, this practice requires significantly greater water volumes. Make sure the irrigation design supplies enough water to the under-canopy area for the tree's requirements. Remember to allow extra capacity in the design to water windbreak trees and to provide more water to the rows of avocados immediately adjacent to windbreak trees.
- **Cater for variability in the orchard** (as discussed above) to allow for the easy interchange of emitters with different delivery volumes for different blocks or trees. For example, it should be easy to remove a 120 L/hour emitter and replace it with say an 80 L/hour emitter for a sick tree and to know, by means of the manufacturer's colour codes, which emitter is which.
- **Good filtration is important** for mini-sprinklers to minimise blockages. When in use, check sprinklers regularly to ensure they are operating correctly.

Potential pitfalls

Several potential pitfalls exist when using under-tree minisprinklers. They are discussed below. (The information is based on M. Harvey's article, *Good sprinkler system needed for avocados*, *Talking Avocados*, Fifth Edition, February–March 1991, p. 8-9.)

Operating pressure. Sprinklers only operate satisfactorily within a restricted pressure range. Outside this range, their performance will deteriorate, either by dumping water at the end of the sprinklers' throw ('donut effect') if the pressure is too low, or misting if the pressure is too high.

Pressure variation. Pressure across the block needs to be checked to ensure variation is not more than about 10%. Large pressure variations lead to uneven watering as more water is delivered by the high pressure sprinklers and less by the low pressure sprinklers. Where pressure variation exceeds 10%, sprinklers need to be fitted with pressure compensators. A well designed system using appropriately tapering irrigation laterals should not need pressure compensators, but they may be necessary for blocks with significant variations in slope and altitude.

Flushing valves. To avoid localised waterlogging and subsequent Phytophthora root rot disease at the ends of irrigation lines, extend laterals beyond the tree rows and fit flushing valves. This ensures that water remaining in the lines after irrigation drains away rapidly and harmlessly.

Sprinkler distribution uniformity. If the sprinklers distribute water unevenly, different parts of the root zone will receive too much water and others too little. Where fertigation is used, this will also mean uneven fertiliser application. This is particularly important for boron fertilisers, where uneven watering can lead to boron toxicity. Where poor quality water is used, uneven watering allows salt build-up in localised areas. Sprinkler uniformity can be measured using the Distribution Uniformity (DU) test. In this test a grid of cans (minimum 35 cans) is placed between sprinklers in the field and the volume of water in each can is measured. To calculate the DU:

$$DU\% = \frac{\text{Average of the lowest quarter} \times 100}{\text{Average of readings}}$$

A DU equal to or greater than 75% is very good, with values less than 67% being unacceptable.

Correct height of sprinkler. The optimum water distribution pattern is achieved when the sprinkler is positioned at the manufacturer's recommended height above the ground.

Worn sprinklers. Sprinklers don't last forever. Every couple of years, check the wear-susceptible components for these signs of wear and tear:

- leaking from the base of the sprinkler when the washers have worn, causing pooling on the ground;
- slow or uneven rotation;
- loss of diameter of throw (worn sprinklers often have a reduced throw).

Blocked sprinklers. Sprinklers with low emitter rates have small apertures and are more likely to be blocked. Blockages can be caused by inadequate filtration, algae build-up, or ants building nests. This generally occurs if the system has not been used for some time. Anti-ant sprinklers are available from some manufacturers. A good management practice is to take a quick run up each interrow on a motorbike and check sprinkler operation at the start of each irrigation.

Animal interference. Large birds such as crows and cockatoos may physically remove sprinkler heads, and rodents may chew laterals. Seek local knowledge on sprinkler types and emitter rates that cope best with these problems.

New irrigation developments

Pulse irrigation. This system, developed in Israel, uses short 'pulses' of irrigation several times a day to keep the shallow feeder root zone continuously moist. In theory, it enables the tree to maintain active water and nutrient uptake for longer periods of the day, potentially increasing productivity and fruit quality. It is becoming particularly popular in areas with hot dry summers such as south-west Western Australia.

Overhead misting. This **experimental** system has been proposed mainly for areas with a Mediterranean climate (for example south-west Western Australia) that experience very hot dry conditions during summer. Under these conditions, the tree 'closes down' (closes stomata and slows the rate of photosynthesis). Overhead misting aims to extend the number of hours that the tree will continue to operate before closing down. The system consists of standard under-tree minisprinklers and a low volume overhead misting system installed in the canopy. The misting system is activated when the temperature in the tree canopy reaches the threshold limit.

Tips for managing with limited water

- Eliminate weed competition near trees, preferably by using a thick layer of mulch.
- Mulch trees, particularly during the drier winter and spring months (subtropical regions), in advance of peak water demand times and high temperatures.
- Choose sprinklers that wet the main root area only.

- Choose an irrigation system that minimises misting—usually achieved by using a high output, low pressure sprinkler.
- Mow the interrow plant cover to keep it from becoming too rank and competing with the trees.
- Irrigate at night. Remember to check sprinkler operation during the day at least once every fortnight.

Soil moisture monitoring systems

For effective irrigation, a monitoring or scheduling system is essential to help you decide when and how much to water. With monitoring, water has a much greater chance of being applied at the right time and in the correct quantity to maximise yield and fruit quality.

A range of equipment and techniques is available for monitoring soil moisture and scheduling irrigation. The most common are the soil-based systems using tensiometers, soil moisture sensors or soil capacitance systems such as EnviroSCAN® and Gopher®. The other main technique is a climate-based system that uses estimates of evapotranspiration. The soil-based systems are preferred and recommended. A brief comparison of the main systems is shown in Table 14.

Irrigation consultants
Section 6 page 5

Table 14. *Comparison of the main soil moisture monitoring systems*

System	Advantages	Disadvantages
1. Tensiometers	• Relatively cheap • Easy to install yourself • Easy to read yourself • Continuous monitoring	• Labour intensive to collect and record data • Requires regular maintenance • Can be inaccurate in extremely wet or dry soil • Not accurate in very sandy soils • Indicates when to irrigate, but not necessarily how much to apply
2. Soil moisture sensors e.g. gypsum blocks	• Relatively cheap • Easy to install yourself • Can be read by yourself • Continuous monitoring possible	• Labour intensive to collect and record data. Requires a digital meter to be brought to each sensor site to take readings • Can be inaccurate in extremely wet or dry soil • Indicates when to irrigate, but not necessarily how much to apply • May only last up to 18 months because of the breakdown of the gypsum
3. Gopher® or Diviner® capacitance probes	• Relatively cheap compared to EnviroSCAN® • Reasonably accurate at all depths and for all soils • Lightweight and portable • Easy to operate and interpret • Indicates both when to water and how much to apply	• Manual reading required; labour intensive to collect and record data
4. EnviroSCAN® or C-Probe® capacitance probe	• Automatic continuous monitoring • Highly accurate at all depths and for all soils • Enables rapid reading and recording of results • Indicates both when to water and how much to apply	• Expensive • Needs skill in interpreting data—training and support recommended • Computer required • Not portable
5. Evaporation pan	• Inexpensive. No in-field measurement is needed because the system uses weather data to predict irrigation needs • Invaluable when planning the orchard to estimate annual requirements and peak demand needs	• Less accurate as system ignores soil variability and the performance of the irrigation system • Requires evaporation and rainfall data • Cannot accurately assess the effectiveness of rainfall received • Error can build up; actual soil moisture needs to be checked periodically

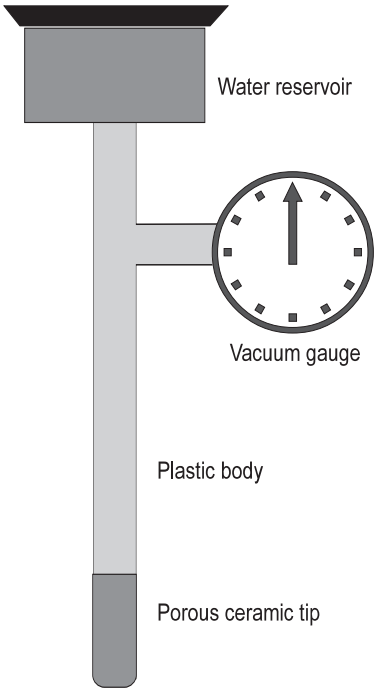


Figure 24. *Parts of a standard tensiometer*

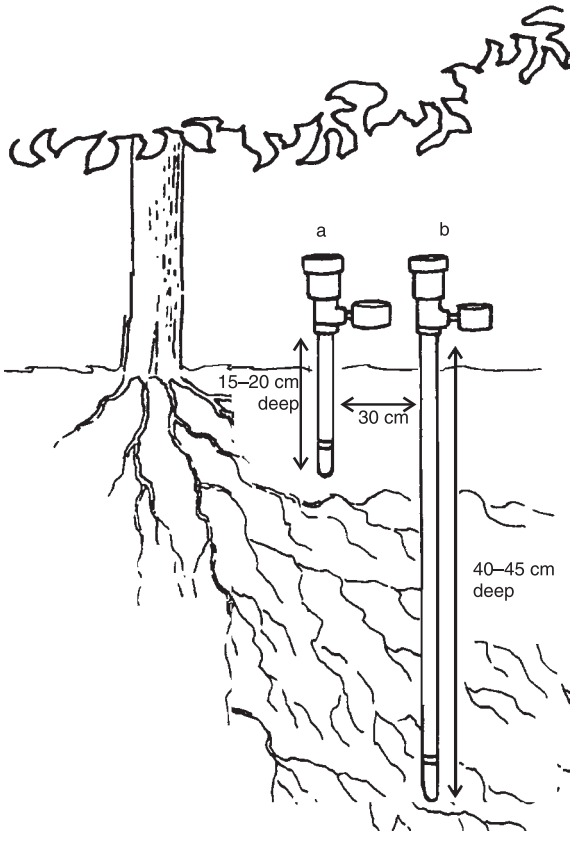
Note that avocado trees draw water mostly from the top metre of soil, with the greatest demand from the top 50 cm. Soil water monitoring devices used for irrigation scheduling need to concentrate on this part of the soil profile. As soil moisture monitoring can be complex, we recommend you seek expert advice when planning and setting up the system.

Tensiometers

Tensiometers, provided they are well sited and maintained, are a relatively cheap and effective way of monitoring soil moisture. They are probably the most commonly used system. A conventional tensiometer consists of four basic parts: a hollow tube filled with water and algaecide, a ceramic tip, a water reservoir and a vacuum gauge which reads water tension on a scale of 0 to 100 centibars (cb) or kilopascals (kPa) (Figure 24). In saturated soil, the vacuum gauge displays 0 kPa. As the soil dries over several days, water moves from inside the instrument, through the porous ceramic tip, into the soil. The gauge reading steadily increases to a maximum of about 90 kPa. When the soil is re-wet after rain or irrigation, water moves from the soil back into the tensiometer and gauge readings fall.

Tensiometer monitoring sites

Tensiometers are installed at monitoring sites throughout the orchard once trees are established. They are left in place until tree growth requires their re-location further out in the active root zone. Use at least one monitoring site for each variety or block. At each site, install two tensiometers: one shallow and the other deep. Position the shallow tensiometer (30 cm long) in the major root zone with its tip 15 to 20 cm deep, and the deep tensiometer (60 cm long) with its tip 40 to 45 cm deep. Place tensiometers on the north-eastern side of healthy trees, under the canopy and where they will receive an average allocation of water from the mini-sprinklers (Figure 25).



If blocks have trees with visible symptoms of Phytophthora root rot, these trees will be over-watered if the scheduling is based on readings from healthy trees. Remember to account for this by replacing the mini-sprinklers under these trees with ones of lower output.

Installing tensiometers

Assemble tensiometers and fill with good quality water to which algaecide has been added. Adding a dye to the water also makes it easy to observe the water level. Leave them to stand in a bucket of water overnight, but preferably for one to two days. The water does not need to be pre-boiled. Tensiometers are more reliable if a vacuum pump is used to remove any air from the tensiometer body and gauge. Make sure the pump fits snugly over the fill point on top of the tensiometer.

Figure 25. *Tensiometers in place, (a) in major root zone and (b) below most roots*

Top up the tensiometers with more water if necessary and use the vacuum pump to remove any air bubbles. They are now ready to install.

The two main principles when installing tensiometers are:

- good contact between the soil and ceramic tip;
- no easy pathways for water to flow directly from the soil surface to the tensiometer tip.

Carry tensiometers to the installation site with the tips either in water or wrapped in wet rags. Do not touch the porcelain tips with your fingers as finger grease can block the fine pores. To install tensiometers follow these instructions in conjunction with Figure 26.

Dig a hole to the required depth and keep the excavated soil nearby in a pile. We have found a 50 mm (two inch) auger the best tool. Place the tensiometer in the hole, over to one side. The next step is critical. Good contact between the ceramic tip and the surrounding soil is most important. Take the most crumbly, moist soil from the dirt pile and pack it around the tip at the base of the hole. A piece of 10 to 15 mm diameter dowel is useful for packing. Don't over-compact the soil into plasticine, but remove large air gaps. Continue replacing soil until the hole is filled. It doesn't matter which soil you use after you have packed the first 5 cm above the tip. Friable topsoil from a few metres away can be used to create a slight mound around the tensiometer. This minimises the risk of water draining down beside the tensiometer, leading to false readings.

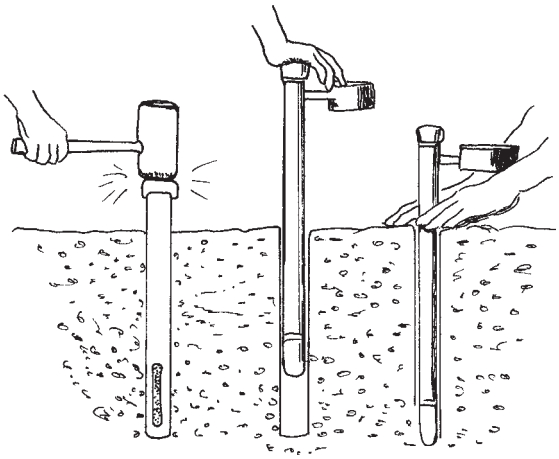


***Figure 26**. Installing deep tensiometers*

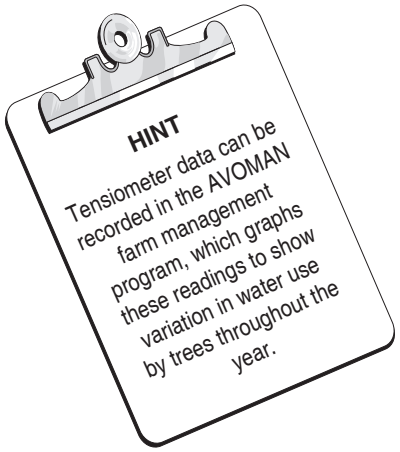
Covers made from silver/blue insulation foil can be placed over the tensiometers to minimise temperature fluctuations and algal growth. The gauge can be left exposed for easy reading.

The tensiometers are now ready to operate. Use the vacuum pump to remove air bubbles. Tensiometers may take a few irrigation cycles to settle down, so don't take too much notice of the readings for the first few days. During this period, air gaps may appear in the tensiometer. Simply refill with algaecide-treated water. Within a week of installation, readings should rise with irrigation or rainfall and fall during a dry spell.

Clearly mark tensiometer locations to avoid damage from tractors and other equipment.

Reading tensiometers

Read tensiometers early in the morning, before 8 a.m., and preferably at the same time each day. At this time there is little water movement in the soil or plant. Read at least twice a week, but preferably every day or second day. Lightly tap the gauge before reading. It is best to read the tensiometers daily for the first few weeks to get a feel for the system.



The shallow tensiometer indicates when to water. The deep tensiometer indicates when the right amount of water has been applied.

Irrigating using tensiometers

Start watering when the shallow tensiometer reads 20 kPa (sandy soils) and 30 to 40 kPa (loam and clay loam soils). Stop watering when the reading falls to 10 kPa (Figure 27). If readings on the deep tensiometer continue to rise immediately after irrigation, not enough water has been added. If readings

on the deep tensiometer fall to less than 10 kPa soon after irrigaton, too much water has been added. Once a week, remove any accumulated air and check that gauges are working using the vacuum pump. Refill tensiometers with clean water.

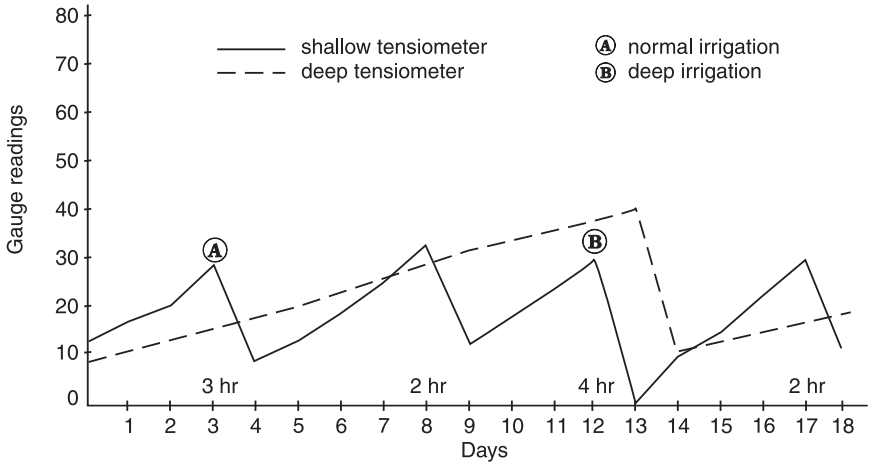
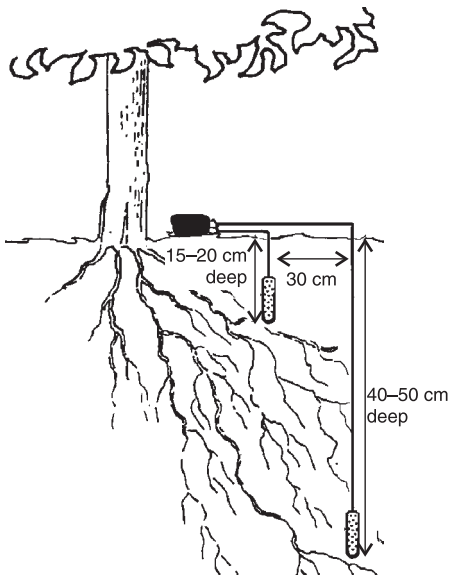


***Figure 27**. A sample chart showing tensiometer readings on a daily basis*

Soil moisture sensors

Soil moisture sensors consist of gypsum blocks which are buried in the soil at strategic points and allowed to assume the same moisture status as the surrounding soil. A pair of wires hooked to the blocks is left exposed at the soil surface and a digital ohmmeter is connected when a reading is desired. The electrical resistance recorded by the ohmmeter is measured as water tension in centibars (cb) or kilopascals (kPa).



Monitoring sites for the blocks are set up in a similar manner to those for tensiometers with two blocks at each site: one at a depth of about 15 to 20 cm and the other at a depth of about 40 to 45 cm. Positioning of the blocks is similar to that shown for tensiometers. The gypsum blocks can be installed in holes similar to those used for tensiometers. Again there must be good contact between the blocks and the surrounding soil and the hole filled to the soil surface (Figure 28).

***Figure 28**. Placement of gypsum blocks*

Irrigation scheduling using gypsum blocks is similar to that recommended for tensiometers, as the device is recording the same soil tension readings.

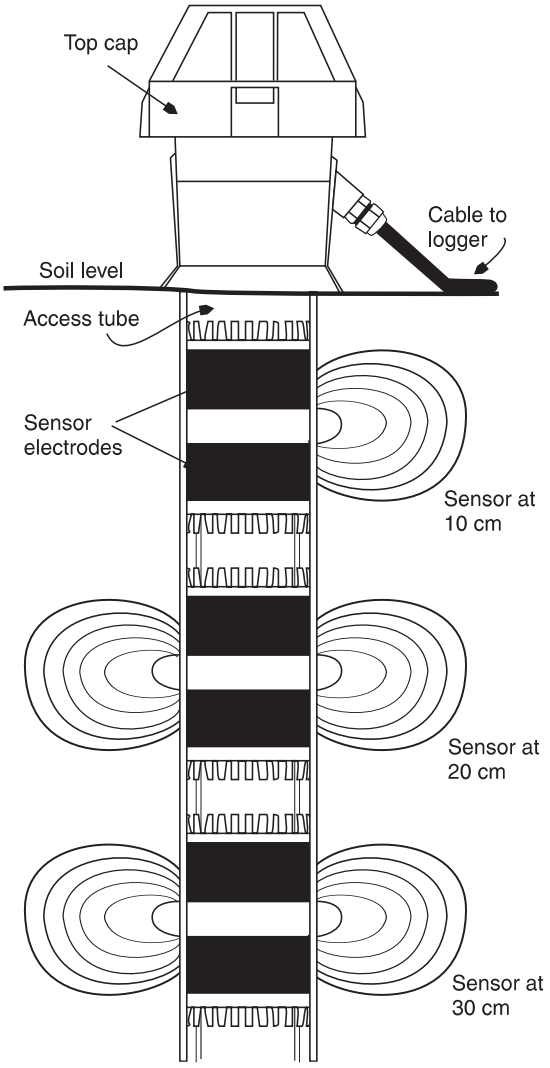


Figure 29. *Diagrammatic representation of an EnviroSCAN® probe*

Capacitance probes

Capacitance probes measure the dielectric constant of the soil which is proportional to its water content. They are available in two forms: a portable version known as the Gopher® or the Diviner® and a non-portable version called the EnviroSCAN® or C-Probe®.

Gopher® and Diviner®

The Gopher® and Diviner® consist of a single sensor on the end of a probe, which is lowered down 50 mm diameter, vertical PVC access tubes installed in the soil. A reading is taken at 100 mm intervals down the access tube and recorded by a hand-held logger. Soil moisture readings can be measured on site or downloaded into a computer and calculated later. The logger can handle up to 99 sampling sites. The machine measures soil moisture in millimetres and can be used to estimate when to water and how much to apply.

EnviroSCAN® and C-Probe®

The EnviroSCAN® and C-Probe® are continuous moisture-monitoring devices consisting of multiple sensors mounted on probes with slots every 10 cm to accommodate the snap-in sensors. The probes are then placed within vertical PVC access tubes installed semi-permanently in the orchard. The probes and tubes are generally left in place for the season and then moved to another tube or site as required. However, a probe can be moved from tube to tube to record readings at several different sites. Sensors are positioned on the probes to provide readings at specific depths. Measurements from the sensors are relayed at set times along a cable to a data logger for recording. Data from the logger are downloaded to a computer every few days to show water use and to provide recommendations for watering. Figure 29 is a diagrammatic representation of the EnviroSCAN® capacitance probe.

A minimum of three probes per block are recommended for avocados, but the number of sites depends on the variability in soil and varieties. When setting up probe sites it is very important that water distribution patterns from the mini-sprinklers are known and that the probes are positioned appropriately. The equipment can be hired from some consultants. As installation of probes and interpretation of the data requires some skill, we recommend you use consultants to set up the system and provide at least initial advice.

Evaporation pan

The evaporation pan technique uses evaporation figures from a pan evaporimeter to calculate water requirements. Evaporation figures for your district are available from the Bureau of Meteorology, or for growers in northern New South Wales from offices of NSW Agriculture, local produce stores and local newspapers. Alternatively, you can install a pan evaporimeter and take regular readings. Evaporimeters are relatively cheap and simple to use.

An avocado irrigation 'ready-reckoner' is shown here for growers wishing to use evaporation to schedule irrigation and to estimate long-term water requirements. The system is invaluable for calculating annual irrigation

requirements and estimating peak demands. Annual irrigation requirements are used to assist in estimating storage requirements and peak demands for designing an irrigation system able to deliver enough water to satisfy crop demands.

Irrigation ready reckoner

Steps:

1. **Determine water requirement**. Go to Table A. Find the line corresponding to your weekly pan evaporation and go across to the column corresponding to the stage of growth. This gives you a figure for **water requirement** (w) in L/m^2 of canopy area/week. Note: For non-bearing trees, use the **winter** column in winter and the **vegetative growth** column in summer.

***Table A**. Water requirement (w) based on total weekly evaporation, stage in growth cycle and pan factor*

Stage in growth cycle		Flower bud break	Flowering	Fruit set	Fruit growth	Large fruit drop	Fruit maturing	Winter	Vegetative growth
Crop factor		0.8	1.2	1.0	0.9	0.9	0.8	0.6	0.7
Pan factor		0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
		Water requirement (w) (L/m^2 of canopy area*/week) – accounts for evaporation, crop factors and pan factor							
Weekly pan evaporation (mm)	**70**	48	71	60	54	54	48	36	42
	65	44	66	55	50	50	44	33	39
	60	41	61	51	46	46	41	31	36
	55	37	56	47	42	42	37	28	33
	50	34	51	43	38	38	34	26	30
	45	31	46	38	34	34	31	23	27
	40	27	41	34	31	31	27	20	24
	35	24	36	30	27	27	24	18	21
	30	20	31	26	23	23	20	15	18
	25	17	26	21	19	19	17	13	15
	20	14	20	17	15	15	14	10	12
	15	10	15	13	12	12	10	8	9
	10	7	10	9	8	8	7	5	6
	5	3	5	4	4	4	3	3	3

* Canopy area is the ground area that the tree canopy covers; it equates to the shaded area under the tree at midday.

2. **Determine the irrigation requirement by adjusting the water requirement for rainfall**. Deduct the effective rainfall* that has fallen to determine the **irrigation requirement** (x)/m^2 of canopy area.

   * Effective rainfall is defined as the amount of rainfall that is judged to have soaked into the soil profile. For example, if 25 mm of rain fell rapidly in 30 minutes, then it is expected that only some has soaked into the soil profile and the rest has run off. Disregard any falls of less than about 5 mm (10 mm in hot subtropical areas such as Bundaberg).

Irrigation requirement (x) = Water requirement (w) – Effective rainfall (mm)

3. **Determine the adjusted canopy area**. Go to Table B and look up **adjusted canopy area** (y) using the tree diameter.

Table B. *Adjusted tree canopy area based on tree diameter*

Tree diameter (m)	Microclimate adjustment*	Adjusted canopy area (y)= (m^2)†
0.5	2.5	0.5
1.0	2.3	1.8
1.5	2.1	3.7
2.0	1.9	6.0
2.5	1.7	8.3
3.0	1.5	10.6
3.5	1.2	11.5
4.0	1.0	12.6
4.5	1.0	15.9
5.0	1.0	19.6
5.5	1.0	23.8
6.0	1.0	28.3
6.5	1.0	33.2
7.0	1.0	38.5
7.5	1.0	44.2
8.0	1.0	50.3
8.5	1.0	56.8
9.0	1.0	63.6
9.5	1.0	70.9
10.0	1.0	78.6
10.5	1.0	86.6
11.0	1.0	95.0
11.5	1.0	103.9
12.0	1.0	113.1

* Adjustment factor to allow for lack of microclimate effect and loss of moisture from root zone of small trees.

† Adjusted tree canopy area = tree diameter x microclimate adjustment factor.

4. **Determine irrigation requirement/tree**. Multiply the **adjusted canopy area (y)** by the **irrigation requirement**/m^2 of canopy area (x) to determine the **irrigation requirement/tree** in L/tree/week (z).

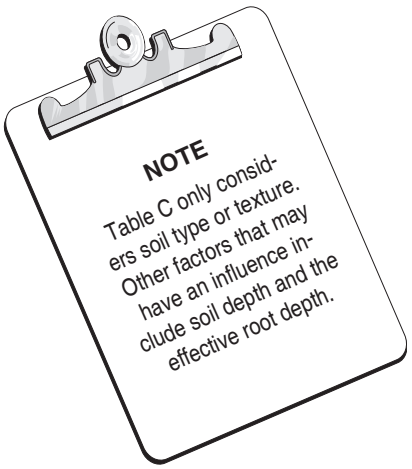
   Adjusted canopy area (y) x Irrigation requirement/m^2 (x) = Irrigation requirement in L/tree/week (z)

5. **Determine number of irrigations/week**. Go to Table C and read the suggested **number of irrigations/week (i)** required for the season and soil type.

Table C. *Guide to number of irrigations per week*

	Clay	Clay loam	Loam	Sandy loam	Sand*
Winter	1	1	1	2	2
Spring	1	2	2	3	7
Summer	2	2	3	4	7
Autumn	1	2	2	3	4

* On the very sandy soils of Western Australia, it is sometimes necessary to irrigate several times a day (refer to the notes on pulse irrigation).



6. **Determine the amount of water to be applied at each irrigation**. Divide the **irrigation requirement in L/tree/week (z)** by the **number of irrigations/week (i).**

Example using the six steps above:

1. The weekly pan evaporation is 35 mm and the trees are in the fruit maturing stage. From Table A, weekly water requirement (w) is 24 L/m^2 of canopy area.

2. There has been 15 mm of effective rainfall during the week. Therefore irrigation requirement (x) is 24 – 15 = 9 L/m^2 of canopy area.
3. The trees have a diameter of 4 m, so the effective canopy area (y) is 12.6 m^2.
4. Irrigation requirement/tree (z) is 9 x 12.6 = 113 L/tree/week.
5. Soil texture is a loam and it is autumn, therefore two irrigations/week are suggested.
6. The amount of water to be applied at each of the two irrigations is therefore 113÷2 = 57 L, three to four days apart.

Irrigation requirements in Australian orchards

To provide some help in understanding the irrigation needs for different regions, a summary of important data is in Table 15.

***Table 15**. Useful data on irrigation requirements for growing regions*

Production area	Climate	Estimated irrigation volume required (ML/ha/yr)	Average annual rainfall (mm)	Typical highest weekly pan evaporation loss of the year (mm/week)	Key comments
Mareeba	Monsoonal summer rain, little rain at other times of year.	8	880	35	Sandy soils, regular irrigation. Water is bought from irrigation scheme and supplied by channel or supplement creek.
Atherton	Mainly summer rainfall; some rain every month. Driest period in spring.	6	1300	35	Generally deep soils with good water-holding capacity. Irrigation mainly required as a supplement.
Bundaberg	Mainly summer rainfall, little rain at other times of the year.	8 – 12	1000	70	Relatively dry. Much of annual rainfall from short intense storms.
Nambour, Alstonville	Mainly summer rainfall; some rain every month. Driest period in spring.	4 – 5	1750 – 1800	40 – 42	Wetter climate with a relatively low irrigation demand. Irrigation required as supplement, particularly in spring.
Sunraysia Mediter-	ranean (hot dry summers, cool wet winters).	10 – 12	285	80	Good irrigation monitoring and scheduling essential. Irrigation of total orchard area helps to grow the interrow sward, reducing the impact of very hot days.
Perth	Mediterranean (hot dry summers, cool wet winters).	15 – 18	820	62 – 75	Irrigation essential. On the very sandy soils in this area, trees need to be irrigated **several times a day** in summer. Pulse irrigation is often practised.
Pemberton	Mediterranean (hot dry summers, cool wet winters).	10	1122	41	Irrigation essential due to hot summers.

Managing crop production: Pest management

Several insect and mite pests attack avocado trees and some of these can cause a significant reduction in fruit yield and quality. Management of these pests requires regular monitoring of the orchard to determine the presence and severity of pest infestations, and the timely and thorough application of pesticides.

Problem pests

More than 30 insect and mite pests attack avocado trees, but only about a dozen cause major problems. These pests are listed in Table 16.

***Table 16**. Major avocado pests in Australia*

Pest	Where it occurs	Tree part affected	How serious
Spotting bugs (fruitspotting bug; banana-spotting bug)	Fruitspotting bug: coastal Qld and NSW Banana-spotting bug: coastal Qld	Fruit	Major pest, particularly near bushland areas
Queensland fruit fly*	Qld and coastal NSW	Fruit	Can be a major pest on thin-skinned varieties such as Fuerte, Rincon and Wurtz. Otherwise, minor
Leaf-eating beetles (Monolepta or red-shouldered leaf beetle; Rhyparida or swarming leaf beetle)	Monolepta: coastal Qld and northern NSW Rhyparida: coastal Qld	Leaves, fruit	Can cause major damage, particularly after rain in spring
Leafrollers (ivy leafroller; avocado leafroller)	Ivy leafroller: coastal Qld and NSW, WA Avocado leafroller: North Qld	Leaves, fruit	Can cause major damage, particularly in Wurtz and Reed
Latania scale	All areas	Leaves, twigs, fruit	Generally minor unless sprays disruptive to beneficial insects are over-used
Fruitborer	North Qld	Fruit	Can cause significant damage in some locations
Ectropis looper	North Qld; Bundaberg–Childers	Leaves, fruit	Generally minor unless sprays disruptive to beneficial insects are over-used
Tea red spider mite	Qld, NSW and WA	Leaves	Can cause major damage, particularly in Wurtz
Garden weevil	WA	Leaves, fruit	Can cause major damage in some locations
Mosquito bug	North Qld	Shoots, fruit	Can cause severe damage to small fruit just after fruit set

* Mediterranean fruit fly occurs in Western Australia and, like Queensland fruit fly, is a minor pest of avocados. However, its presence means growers must meet specified disinfestation procedures for export to other states.

Spotting bugs (Fruitspotting bug and banana-spotting bug)

The pest

- Fruitspotting bug (*Amblypelta nitida*) and banana-spotting bug (*Amblypelta lutescens lutescens*).
- Adult bugs are yellow-green, about 15 mm long, with long legs and antennae. They can be difficult to find because, when disturbed, they either fly away or quickly hide. Immature stages (nymphs) are ant-like in the very young stages, pink to red-brown (sometimes green), with prominent antennae and button-like scent glands on the upper side of the abdomen. The scent glands are most prominent in the banana-spotting bug. Pictures of both spotting bugs are in the *Problem Solver*, page 25.

Life cycle

- Females lay single, pale green, oval-shaped eggs, about 2 mm long, on fruit, flowers or leaves. After hatching, the bugs pass through five nymphal stages before they become adults. During summer, the spotting bug life cycle takes five to six weeks. There may be four overlapping generations spanning the period from spring through to autumn. The adults from the autumn generation persist over winter, often retreating to native plant hosts in bushland, to windbreaks or to ornamental plants. Activity restarts in spring, when temperatures rise and the first immigrants infest orchards during flowering and fruit set. The bugs are more prevalent in orchards adjacent to bushland, particularly rainforest.

Damage

HINT

Pictures of spotting bug damage are in the *Problem Solver*, pages 25, 30 33 and 41.

- Feeding by both adults and nymphs damages the fruit. The bugs insert their long mouthparts into the flesh and suck out the cell contents. During feeding, they inject toxic saliva, which kills the cells. As the fruit grows and expands, stress fractures result in the development of star-shaped cracks, sunken craters, and surface lumps. Damage is often accompanied by sap secretions, which dry to a white powder on the surface of the fruit. Generally the fruit ripens normally in spite of the damage. In Hass, 'blind stings' occur, which may not be detected at harvest. When this fruit is finally consumed, each unseen feeding site may show in the flesh as a small hard lump. In thin-skinned varieties, damage may hasten the development of anthracnose disease.
- Small fruit that have just set when attacked generally fall. Older fruit may be retained on the tree, but the damaged fruit are generally unsuitable for commercial marketing.
- Some fruitspotting bug damage can be difficult to distinguish from that caused by Queensland fruit fly. This can be checked by cutting a section through the affected tissue. Spotting bug damage penetrates deeply into the flesh and is surrounded by dark, water-soaked discolouration. If there are only a few fruitspotting bug lesions, these are generally more prevalent on the neck of the fruit. On the other hand, fruit fly damage is superficial, penetrating no more than about 3 mm into the flesh, and producing a hard, pear-shaped callus. Small banana-shaped eggs may also be present inside the callus. Fruit fly damage is also generally more evident on the bottom half of the fruit.
- Fruit is damaged mainly from October to April. All varieties are attacked, but damage is more noticeable on the thin-skinned varieties such as Fuerte, Rincon, Wurtz and Shepard.

- Spotting bugs attack a wide range of crops including macadamia, lychee, custard apple, mango, longan and papaya. Many ornamental plants such as frangipanni, hibiscus, bauhinia and some eucalypts may also be used by spotting bugs for feeding and breeding.

Management

- See notes on monitoring and management on page 122.

Queensland fruit fly

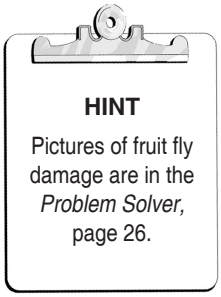
The pest

- *Bactrocera tryoni*.
- Adult flies are wasp-like, about 6 mm long and reddish-brown with yellow markings. When at rest on leaves or fruit, the wings are held horizontally and may move backwards and forwards in a 'rowing' motion. A picture of fruit fly is in the *Problem Solver*, page 26.

Life cycle

- The adult female fly lays small, pearly-white, banana-shaped eggs in batches under the skin of fruit. In green fruit, a hard callus develops around the eggs and they fail to hatch. However, the damaged skin means fruit is downgraded in quality. In ripe fruit, the eggs may hatch and the white larvae (maggots) destroy the flesh. When fully grown, the larvae emerge from the fruit, fall to the ground and pupate. Adults emerge when conditions suit. During the summer, an average life cycle takes about two to three weeks.

Damage



- The damage is essentially of a cosmetic nature.
- Freshly punctured green fruit exude a very small quantity of clear gum, which dries to form a white powdery deposit on the skin. A star-shaped crack develops on the fruit surface around the puncture.
- Damage may be difficult to distinguish from that of spotting bug (see above).
- Most damage is from December to April. All varieties are susceptible, but damage is generally confined to the thin-skinned varieties such as Fuerte, Rincon and Wurtz.
- Affects many other crops, particularly citrus, stonefruit and mango.

Management

- See notes on monitoring and management on page 123.

Leaf-eating beetles (Monolepta beetle; swarming leaf beetle)

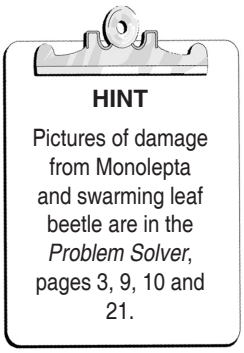
The pest

- Monolepta beetle or redshouldered leaf beetle (*Monolepta australis*); swarming leaf beetle or Rhyparida beetle (*Rhyparida* spp.).
- Monolepta beetles are about 4 mm long and yellow with a red spot at the top of each wing cover.
- Swarming leaf beetles are brown or black and from 3 to 5 mm long. Pictures of both beetles are in the *Problem Solver*, pages 3 and 9.

Life cycle

- Adult beetles lay eggs in the surface soil of grass areas, particularly paspalum and kikuyu pastures. Eggs hatch into larvae about 5 mm long, which feed on the grass roots. The larvae eventually pupate in the soil and adult beetles emerge following rain, especially in spring.

Damage



HINT

Pictures of damage from Monolepta and swarming leaf beetle are in the *Problem Solver*, pages 3, 9, 10 and 21.

- The beetles may damage leaves, flowers and fruit. While the presence of individual beetles is of little concern, swarms of beetles can completely strip the leaves and the skin from fruit on individual trees within a few hours.
- Leaf damage first appears as brown, lace-like marks, but when severe, leaves appear scorched. Affected fruit take on a brown, suede-like appearance as the surface skin layers are removed, exposing the underlying tissues to desiccation.
- Damage is often patchy throughout the orchard.
- May attack many crops and ornamental plants. Monolepta beetle is particularly attracted to some eucalypt species such as Cadagi (*Eucalyptus torelliana*) and Dunn's white gum (*Eucalyptus dunnii*).

Management

- See notes on monitoring and management on page 123.

Leafrollers

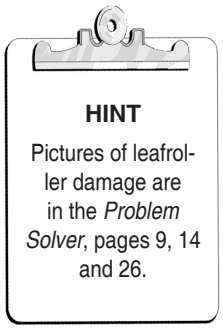
The pest

- Avocado leafroller (*Homona spargotis*); ivy leafroller (*Cryptoptila immersana*).
- Adult moths are a mottled grey to light brown and up to 25 mm long. At rest, the moths have their wings folded slightly downwards from the horizontal midline of the body and appear bell-shaped. The larvae of the ivy leafroller grow up to 25 mm long, and are a translucent green-yellow, with a white head capsule that bears four distinct black, wedge-shaped marks. Larvae of the avocado leafroller are green, with two black patches on the white head capsule. A picture of a larva of ivy leafroller is in the *Problem Solver*, page 26.

Life cycle

- The pale yellow (avocado leafroller) or green (ivy leafroller) eggs are laid in masses, sometimes exceeding 400, and overlapping like fish scales. They are laid on the upper surface of mature leaves. Eggs hatch after six to eight days, with the larvae dropping on silken threads to be dispersed by the wind or crawl a short distance to suitable feeding sites. They feed for up to six weeks before pupating. A picture of the egg masses of avocado leafroller is in the *Problem Solver*, page 3.

Damage



HINT

Pictures of leafroller damage are in the *Problem Solver*, pages 9, 14 and 26.

- The caterpillars roll and web leaves together, and web leaves to fruit to form shelters in which they feed and develop. Inside these shelters they feed on adjacent leaf and fruit tissue. Although leaf damage may be severe, fruit damage is more important. Large areas of the fruit skin may be eaten, sometimes to a depth of 4 mm. Damaged fruit may be infected with anthracnose and drop, or the injury may heal, forming scar tissue. In either case, fruit is unmarketable. Avocado leafroller may also defoliate trees.
- Varieties worst affected are Wurtz and Reed, which form dense leaf and fruit clusters that the larvae find easy to web together. In Wurtz, the leaves often hang over the fruit and severe damage is common.
- Avocado leafroller can be a serious problem from spring to autumn, but ivy leafroller is mainly a problem in autumn.

- Both leafrollers may attack a range of other plants including custard apple, tea, macadamia, citrus, cotoneaster and honeysuckle.

Management

- See notes on monitoring and management on page 124.

Latania scale

The pest

- *Hemiberlesia lataniae*.
- Adult scale insects are shield-shaped and yellow, with hard, grey-brown to creamy-brown, semi-translucent scale covers. The scales measure 1 to 1.3 mm across. Pictures of latania scale are in the *Problem Solver*, pages 2, 17 and 23.

Life cycle

- Female scales lay many eggs under their scale covers. These hatch in about seven days into tiny crawlers, which move about on the tree or are dispersed on the wind. When crawlers eventually settle, they start to feed and grow scale covers, passing through two growth stages before becoming mature adults.

Damage

- Affects branches, twigs, leaves and fruit. Unless the scale infestation is severe, there is little effect on the tree. However, fruit infestations are a cosmetic problem leading to downgrading in quality. Scales can be physically removed from smooth-skinned fruit during postharvest brushing, but are difficult to remove from rough-skinned fruit such as Hass.
- More serious in later-maturing varieties such as Hass, as the longer the fruit are on the tree, the greater the opportunity for scale to build-up.
- Affects a wide range of crop plants and ornamentals.

Management

- See notes on monitoring and management on page 124.

Fruitborer

The pest

- *Thaumatotibia zophophanes*.

Life cycle

- Relatively little is known about its habits. The very small, flattened eggs are laid singly on the fruit and the larva burrows almost immediately into the skin. The larva feeds and develops in the flesh just below the rind. When mature, it emerges from the fruit to pupate elsewhere in the tree or in the leaf litter below the tree.

Damage

HINT
A picture of the damage from fruitborer is in the *Problem Solver*, page 28.

- The entry site of the larva is marked by a white powdery residue and in the early stages resembles damage caused by fruit fly or fruitspotting bug. Excreta produced by the larva accumulate at the entry site. As the larva continues to feed, mining below the skin, a black spot develops on the skin above the feeding site. The damage generally makes the fruit unmarketable.
- Hass is the variety most affected.

Management

- See notes on monitoring and management on page 125.

Ectropis looper

The pest

- *Ectropis sabulosa.*
- The adult moths are relatively large with a wingspan of 30 to 45 mm. Wings and body are light brown to grey with fine dark markings. During the day while the moth is resting, it spreads its wings and remains motionless. Because of its colour, it is well camouflaged against the bark of the trunk. The larvae (called loopers) are 15 to 20 mm long, grey-brown to dark brown or black, with velvety patches on the body, and they move with a typical looping action. If disturbed, they stiffen to resemble a small twig. A picture of a larva of ectropis looper is in the *Problem Solver*, page 27.

Life cycle

- Adult moths lay green eggs in clusters of up to 750 under the old bark of the lower trunk and main limbs. Before eggs hatch, they turn grey. Young loopers move to foliage or fruit and pass through several growth stages before pupating.

Damage

- Fruit and leaves may be affected. In severe infestations, trees may be completely defoliated, exposing the tree to sunburn. The larvae remove the skin of fruit, leaving shallow, rough brown scars. Pictures of fruit and leaf damage from ectropis looper are in the *Problem Solver*, pages 27 and 43.
- Damage is more severe in trees adjacent to windbreaks.

Management

- See notes on monitoring and management on page 125.

Tea red spider mite

The pest

- *Oligonychus coffeae.*
- The adult mite is a dark maroon to almost black spider mite about 0.5 mm long. Nymphal stages are also maroon-coloured. A picture of the mites is in the *Problem Solver*, page 11.

Life cycle

- Mites prefer older, mature leaves. Females lay pinkish eggs with a pointed top. Eggs hatch in five to seven days. The two active immature stages take about two weeks to mature to adults.

Damage

- Mites mainly infest the upper leaf surfaces. Damage shows as bronzing of the leaves. In severe infestations, the upper leaf surface becomes littered with the whitish cast skins of the mites.
- More common in autumn in the varieties Wurtz, Pinkerton, Hass and Sharwil. Pictures of the damage are in the *Problem Solver*, page 11.

Management

- See notes on monitoring and management on page 125.

Garden weevil

The pest

- *Phylctinus callosus*.
- The adult weevil is about 7 mm long with a typical weevil snout and a prominent pale white, V-stripe across its rear. Larvae are about 6 mm long, legless, with a brown head capsule. They feed on the roots. A picture of an adult weevil is in the *Problem Solver*, page 15.

Life cycle

- Larvae develop in winter and pupate in early spring. Most adult weevils emerge during late spring and early summer.
- As adult weevils are not very mobile, infestations spread slowly. It is common to see infestations in the same location year after year.

Damage

- Leaves and fruit are affected. Leaves show symptoms varying from holes to a complete skeletonising. Fruit stalks may be ringbarked, reducing fruit size. Affected fruit have small discrete patches gouged in the skin. The pest may also damage roots.
- Damage is generally more common on the lower parts of the tree.
- Affects a wide range of weeds and crop plants including stonefruit, grapes and strawberries. Pictures of weevil damage are in the *Problem Solver*, pages 15 and 22.

Management

- See notes on monitoring and management on page 126.

Mosquito bug (Helopeltis bug)

The pest

- *Helopeltis* spp.
- Adult bugs are small (about 7 mm long) and slender, with long antennae. They vaguely resemble mosquitoes, but a distinguishing feature is a pin-like projection on the chest of both nymphs and adults. A picture of the bug is in the *Problem Solver*, page 17.

Life cycle

- Adult female bugs lay small eggs (1 mm across) into the soft tissues of shoots. Nymphs pass through several stages over three to five weeks before developing into adults.

Damage

- Nymphs and adults feed on young thumbnail-size fruit causing numerous small black spots on the surface.
- Young shoots may also be affected with small dark spots on the stems and along the leaf veins. These spots crack, causing wilting and collapse of the shoot tip. Pictures of bug damage are in the *Problem Solver*, pages 17 and 23.

Management

- See notes on monitoring and management on page 126.

Approaches to pest management

Approaches to pest management have changed significantly in recent years. This is in response to a need for more cost effective procedures, as well as the need to reduce chemical use. To better understand the new approach to pest management, it is important to first contrast it with the older 'traditional' approach.

The traditional approach to pest control

The traditional approach to insect pest control was to apply routine calendar sprays of chemicals. This approach had several problems.

- It was a waste of money if the pests were absent.
- Even when pests were present, it disregarded the fact that trees can tolerate small numbers of pests without significantly affecting yield and quality. In these cases, the cost of spraying is much greater than the benefit gained by controlling the pest.
- It increased the risk of chemical damage to the fruit.
- It was costly.
- It relied heavily on new chemicals being developed to replace those for which insects had developed resistance. This contradicts the modern reality where fewer new chemicals are being discovered and developed.
- It was severe on beneficial insects and mites and sometimes resulted in outbreaks of pests that were well controlled naturally.
- It exposed the farm family and farm employees to a range of chemicals.
- It increased the amount of chemical residue in both the fruit and the environment.

The modern approach to insect pest control—IPM

The modern approach to insect pest control involves less reliance on chemicals by using all or several complementary control measures together in a program known as *Integrated Pest Management* (IPM). There are several key elements of IPM:

- Using cultural control measures such as crop hygiene and the growing of less susceptible varieties.
- Using biological control measures such as naturally occurring parasites, predators and pathogens (known as *natural enemies* or *beneficials*) of the insect pests.
- Using chemicals only where necessary. Preference is given to chemicals that are compatible with beneficial insects and 'softer' on the environment.
- Using bait sprays instead of cover sprays for pests where it is appropriate, for example, fruit fly.
- Carefully applying chemicals with well-calibrated spray equipment to avoid crop damage, excess residues and off-site pollution.
- Checking the crop regularly to determine when pests are present and taking action only when pests are present and at damaging levels. This process of checking the crop for pests is called monitoring.

Monitoring pests

Monitoring works by first determining pest action levels—the pest populations at which damage is considered worthy of attention. The action level is the point at which the damage is roughly equivalent to the cost of control. Pest populations are then regularly monitored and control measures applied only when pest populations approach or reach this action level. Monitoring then continues to allow pest populations to be managed at or below this action level. As well as the pests, the beneficial insects and mites, which naturally attack the pests, are also monitored. In some cases, they alone will be sufficient to keep the pest populations in check.

Monitoring requires skill in observing and identifying pests and beneficials. This requires considerable training and experience. For this reason, we recommend using professional pest monitoring consultants.

Pest monitoring consultants
Section 6 page 5

These consultants visit the orchard regularly during the main part of the season to monitor pest populations. After each visit, they provide a report on pest status, and required action. The cost of using a pest consultant varies, depending on tree density and pest and disease status of the orchard.

Note: Diseases are difficult to monitor in the same way that insect pests are monitored. A disease is microscopic and, in most cases, by the time you see symptoms, it is well established and difficult to control. We therefore rely on preventative sprays to control most disease problems. Monitoring is still useful for detecting obvious problem areas and for evaluating how well your disease prevention program is working.

Do-it-yourself monitoring

If you wish to do the monitoring yourself, we suggest you first get some training from a pest consultant. Here are the main requirements for monitoring.

Materials

- x10 hand lens, magnifying glass or small stereo microscope.
- Notebook, prepared monitoring charts and pen.
- Plastic bags or small bottles and marking pen for samples.
- Sharp pocket knife.
- Roll of coloured plastic tape.

Other

- Commitment and the time to monitor regularly, at least every week to 10 days.
- Good eyesight.
- Good knowledge of the pests and beneficial insects and mites.
- Common sense.

Monitoring is not intrinsically difficult. It is just a process of systematic observation and recording.

How many trees to monitor

Define your orchard as blocks. A block is trees of the same variety and about the same age. Each block should be monitored separately. If your orchard consists of trees of the same variety and age, then treat it as one block.
For most pests, closely examine up to five trees at several different loca-

tions throughout each block. A total of 20 trees/block (five trees at four locations) should be sufficient. If you have less than 1 ha in any block, then check at least 10 trees in that block. Planting density does not affect the number of trees you need to monitor.

How often to monitor

Although monitoring is useful throughout the year, the critical period is from fruit set to June (or harvest if earlier than June). During this period, monitor every fortnight, but preferably weekly. During the remainder of the year, monitor trees every month or so for scales and other incidetal pests.

Monitoring procedure

Prepare some monitoring charts to record the results of your monitoring. An example of a monitoring chart is shown in Figure 30.

PEST MONITORING CHART

Orchard:

Block:

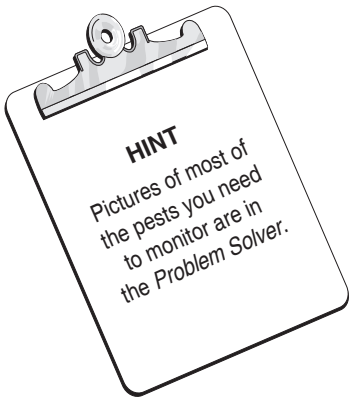
Date:

Tree no	Pest or disease							Beneficials			
	FSB*										
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
TOTAL											
%											

* Insert your own pest codes in the column headings, e.g. FSB—fruitspotting bug.

***Figure 30**. Sample pest monitoring chart*

Each time you monitor, select trees randomly, but from different parts of the block. While moving between these selected trees, keep alert and visually scan intervening trees. Inspect some fruit selected at random from each of the selected trees in the block. The fruit do not have to be picked unless they are damaged by spotting bug or severely damaged by other pests.



Check any fruit symptoms with your hand lens. If you collect samples for later examination in the shed or office, place them in a plastic bag inside an esky. Mark the sample with the block number and date.

It is best to do the monitoring on foot rather than drive, as trees can be inspected more thoroughly. Pay particular attention to the edges of the orchard adjacent to rainforest, windbreaks, and watercourses as these are often the areas where pests first enter the orchard.

After each monitoring, transfer the results from your monitoring charts to an orchard record for the full season. This will form a permanent record of the trend for each pest and beneficial insect over the season, and will be very valuable once data has been recorded over several years. This is particularly valuable in identifying patterns and hot spots of pest incidence for monitoring in future seasons.

Monitoring and management of major pests

Guidelines for monitoring and managing the major pests of avocado are shown in Table 17. **Note that pesticide chemicals are listed in the *Problem Solver Handy Guide***. A pest and disease management program is in the *Pest Management Handy Guide*.

***Table 17**. Monitoring and management guidelines for major pests*

Spotting bugs

How to monitor

- Monitor trees across the orchard, but pay particular attention to trees adjacent to bushland and known hot spots. Note hot spots for future monitoring.
- Watch fruit in the tops of trees as these are often the worst affected.
- Record the presence or absence of spotting bug damage on 10 randomly selected fruit per tree. Remove affected fruit during monitoring so that only new damage will be seen at each sampling.
- Thin-skinned varieties are easy to monitor, but care is required with thick-skinned varieties such as Hass, as damage, particularly late damage, is difficult to detect.

When to monitor

- Weekly from fruit set to mid-April (or harvest if earlier).
- Even after monitoring has indicated spraying should start, continue to monitor bug damage to check spraying efficacy and determine the appropriate spray interval.

Comments

- Monitoring of the bugs themselves is difficult, as they are elusive and well camouflaged. Instead, monitor fruit for early signs of damage.
- Although small fruit damaged early generally falls during natural fruit drop, we recommend monitoring from fruit set because it provides a very good indication of the build-up of bug nymphs.
- Spreading a white sheet or canvas under a tree before spraying is a useful way of checking for dead bugs and other insects.

Management

- Start spraying as soon as significant early bug damage is detected (2%

or more fruit with fresh damage). Continue at 14 to 28 day intervals until mid-April or harvest (if earlier). Use the shorter interval in areas adjacent to bushland or known high-incidence areas.

- Where possible, only spray the infested parts of the orchard.
- Ensure thorough coverage. Mature orchards with canopies touching across the rows should be pruned to facilitate spraying, as well as to increase the area of fruiting canopy.
- Spray all varieties.
- Beneficial insects that parasitise spotting bug eggs reduce the potential bug numbers, but no commercially-significant natural control occurs in orchards.

Queensland fruit fly

How to monitor

- Monitoring is generally necessary only on thin-skinned varieties (Fuerte, Rincon, Wurtz) or in known hot spot locations. In these cases, monitor trees across the orchard.
- Record the presence or absence of fruit fly damage on 10 randomly selected fruit per tree. Be careful to distinguish from fruitspotting bug damage.

When to monitor

- Weekly from October to mid-April (or harvest if earlier).
- Even after monitoring has indicated spraying should start, continue to monitor fly damage to check spraying efficacy and determine the appropriate spray interval.

Comments

- Monitoring of the flies is difficult, because damaging numbers may escape visual detection. Traps are of some value, but should not be relied on for monitoring. Monitoring fruit for early signs of damage is the most accurate method.

Management

- Regular sprays applied for fruitspotting bug should suppress fruit fly populations sufficiently without the need for special sprays. Otherwise, start spraying as soon as fly damage is detected.
- Use bait sprays rather than cover sprays. Bait sprays are a mixture of pesticide and fly feeding attractant applied to a small section of the tree. These have minimal effect on beneficial insects. Spray at 7 to 14 day intervals until mid-April or harvest (if earlier). Apply as a low-pressure coarse spray in a strip or patch low down on the tree skirt. Apply about 50 to 100 mL/tree. Reapply after rain.

Leaf-eating beetles (Monolepta beetle, swarming leaf beetle)

How to monitor

- Monitor trees across the orchard, but pay particular attention to trees on the edge of the orchard adjacent to eucalypt windbreaks.
- As some eucalypt species such as *E. torelliana* and *E. dunnii* are particularly attractive to the beetles, monitor these closely for early indications of beetle activity.
- Look for swarms of beetles on leaves, flowers and fruit.

When to monitor

- In highly susceptible areas, monitor at least weekly during spring and summer (preferably two to three times a week). It is important to detect the arrival of swarms early.
- In particular, be very vigilant after rain in spring, especially if preceded by a long dry period. This is when the maximum number of beetles will emerge.

Comments

- Some districts have regular problems with leaf eating beetles and orchards may be invaded several times a year. In these locations, it is useful to set up a 'neighbourhood watch' to advise each other of the arrival of swarms.

Management

- When swarms are detected, spray quickly. If restricted to sections of the orchard or windbreak trees, spot spray just those trees or windbreaks affected.

Leafrollers

How to monitor

- Monitor trees across the orchard. Pay particular attention to the highly susceptible varieties (Wurtz and Reed).
- Look for webbing and dead leaves attached to fruit and record numbers of webs/larvae per tree.

When to monitor

- Fortnightly throughout spring and summer for avocado leafroller and predominantly throughout autumn for ivy leafroller.

Comments

- With avocado leafroller, it is vital to monitor activity early in spring before flowering, to avoid the early establishment of webs. Monitoring egg masses helps to identify likely outbreaks.

Management

- Start spraying when 10 or more webs/larvae per large tree are recorded.
- Because of their secluded habits, larvae are difficult to control with contact insecticides. One of the registered treatments uses a fumigant added to the spray to flush larvae out of their shelters. Do not use the fumigant under cool conditions, as warm temperatures (more than 15°C) are needed for the fumigant action to operate.
- Several natural enemies have been recorded attacking leafrollers. For this reason, it is important to minimise the long-term use of disruptive pesticides.

Latania scale

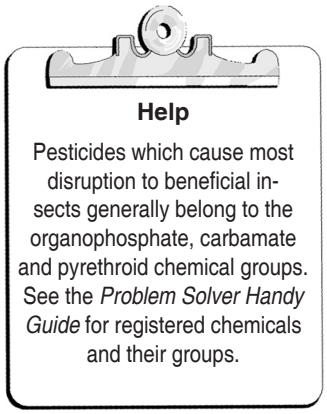
How to monitor

- Monitor trees across the orchard.
- Record the extent of infestation of scales on leaves and twigs and the numbers of scales on 10 randomly selected fruit per tree.
- Pay particular attention to areas of the orchard where scale was recorded in the previous season.

How to monitor

- Monitor every 14 days during December to January when young crawlers are active. Monitor monthly at other times of the year.

Management



Help

Pesticides which cause most disruption to beneficial insects generally belong to the organophosphate, carbamate and pyrethroid chemical groups. See the *Problem Solver Handy Guide* for registered chemicals and their groups.

- Normally kept under reasonable control by beneficial insects except where there has been prolonged use of disruptive pesticides.
- The suggested action level is where scales are very obvious on leaves and twigs, or scales on fruit exceed 4 per fruit (rough-skinned varieties) or 20 per fruit (smooth-skinned varieties). When action level is reached, spray with narrow range oil when crawler production has ceased and before scale produce their scale covering. Avoid applying oil sprays during hot weather. To be effective, oil sprays need to be applied at high volume and achieve very good coverage.
- Where scale was a problem in the previous season, apply narrow range oil before flowering or soon after fruit set.

Fruitborer

How to monitor

- Monitor trees along the boundary of the orchard, particularly those on the side facing the main prevailing winds or where damage has occurred in previous years.
- Inspect at least 100 fruit on 10 trees. Look for fruit damage and the presence of fruitborer eggs.

When to monitor

- Monitor from when fruit is half-grown (generally about October in North Queensland)

Comments

- Spray when fruitborer damage or eggs are detected. No pesticides are yet specifically registered for the pest, but the sprays used for fruitspotting bug generally provide an adequate level of control.

Ectropis looper

How to monitor

- Monitor trees across the orchard, but pay particular attention to trees adjacent to windbreaks.
- Look for looper caterpillars and check for parasitism by *Apanteles* wasps (white cotton-like clusters about 5 mm long attached to larvae). Also record the extent of defoliation and fruit damage.

When to monitor

- Monitor regularly throughout the year, but weekly during early spring when young fruit are developing.

Management

- Spray when defoliation or fruit damage is severe and parasitism by *Apanteles* wasps is not present.

Tea red spider mite

How to monitor

- Monitor trees across the orchard, paying particular attention to trees of the more susceptible varieties (Wurtz, Pinkerton, Hass, Sharwil).

- Record the percentage of foliage bronzed. Also closely examine the upper leaf surfaces and record the presence or absence of both live mites and natural predators (*Stethorus* ladybirds and lacewings). See page 11 of the *Problem Solver* section for a picture of *Stethorus* ladybirds.

When to monitor

- Monitor weekly from January through to autumn and at least monthly during the remainder of the year.

Management

- Trees can tolerate a moderate infestation without significant damage. The mites are also generally well controlled naturally by *Stethorus* ladybirds and lacewings, except where there has been prolonged use of disruptive pesticides.
- Spray where more than 20% of foliage is bronzed, live mites are present, and good numbers of natural predators (*Stethorus* ladybirds and lacewings) are absent.

Garden weevil

How to monitor

- Monitor trees across the orchard, paying particular attention to areas of the orchard where the problem has been detected before.
- Check trees for leaf and fruit damage low down on the tree where branches are close to ground.

When to monitor

- Monitor fortnightly from early spring through to mid-summer.

Management

- Spray when fruit damage is first detected. Trees can tolerate some leaf damage without significant effect. We recommend that spraying be delayed until fruit damage is detected unless leaf damage is particularly severe. This minimises any disruption to beneficial insects from prolonged use of the broad spectrum chemicals used to control the pest.
- Where possible, spot spray affected trees only.
- Remove low branches close to or in contact with the ground.

Mosquito bug

How to monitor

- Monitor trees across the orchard.
- Check 10 newly set fruit for presence of the small dark spots from bug feeding. Also check for shoot damage.

When to monitor

- Monitor weekly for the month immediately after fruit set. Check for shoot damage during the remainder of the year.

Comments

- The presence of bugs is difficult to assess, as they are timid and fly away if disturbed. However, feeding damage is obvious and easy to record.

Management

- If fruit damage is detected within the month following fruit set, apply sprays for fruitspotting bug, as these also control mosquito bug.

Anthracnose management

After Phytophthora root rot disease, anthracnose is the next most important disease problem of avocados. It is a serious problem for the industry because symptoms generally only show at the consumer end of the chain when fruit ripens. It has consequently become the major issue for consumers when selecting fruit. To ensure consumer confidence is maintained, all growers have a responsibility to properly manage anthracnose.

Understanding the disease

Cause

Anthracnose disease is caused by the fungus *Glomerella cingulata* (*Colletotrichum gloeosporioides*).

Factors affecting incidence

Climate. The disease is favoured by warm (more than 15°C), humid conditions. Although it can occur in all production areas, particularly in wet years, it is most serious in districts with high summer rainfall in the subtropical and tropical regions of eastern Australia. In south-west Western Australia with its dry summers, the critical periods are autumn and spring.

Variety. Varieties differ in their susceptibility to the disease. Fuerte, Rincon and Wurtz are the most susceptible while Hass, Pinkerton and Sharwil have the greatest tolerance. The more tolerant varieties have higher levels of antifungal compounds, called dienes, in the skin. However, all varieties require an effective fungicide spray program. For example, a common misconception is that Hass does not suffer from anthracnose. While it is unusual to find visible symptoms on Hass fruit in the orchard, poorly protected fruit will often develop moderate to severe anthracnose when ripening. This is largely masked by the colour change in the fruit and is often only discovered when fruit are cut in preparation for consumption.

Rootstock. Recent research has indicated that rootstock may play a significant role in the susceptibility of the scion variety to anthracnose. For example, Duke 6 and Duke 7 appear to increase the susceptibility of Hass fruit to anthracnose when planted in the wetter coastal areas of eastern Australia.

Crop management. Poor aeration of the tree canopy from a lack of appropriate pruning and canopy management increases the risk of anthracnose infection. Dead wood and dead leaves tangled in the canopy act as a reservoir of fungal spores. Damage from fruitspotting bug and fruit fly increase the

incidence of preharvest anthracnose. Calcium and nitrogen nutrition also appear to play a role in the susceptibility of fruit to infection.

Symptoms and damage

Two types of preharvest symptoms are commonly found:

- Small dark spots which occur around the fruit breathing pores or lenticels. Often a teardrop pattern of spots can be observed as the infection runs from the top to the base of the fruit. This occurs when fungal spores are carried down the fruit by water during extended rainfall periods. All varieties are susceptible to this type of infection. The spots rarely penetrate the ripened flesh, but downgrade the cosmetic appearance of the fruit.
- Large, circular, sunken brown spots. These occur when the fungus infects fruit through damaged areas such as insect feeding, egg-laying punctures or mechanical injury to the skin (for example, hail and wind rub). This type of infection is most commonly seen on the more susceptible varieties such as Fuerte, Rincon and Wurtz).

NOTE

Another field symptom caused by the anthracnose fungus has recently been confirmed. This is called 'pepper spot', and as the name suggests, causes a myriad of tiny black spots on fruit and twigs. Pictures of pepper spot are in the *Problem Solver*, pages 18 and 21.

more info
Anthracnose symptoms
Section 5 pages 20, 36 and 38

Postharvest development of anthracnose disease is mainly due to what are known as latent infections. These are essentially field infections, which develop in the skin as fruit begins to ripen. Before fruit ripen, naturally occurring antifungal compounds (dienes) are present at sufficient levels to prevent disease development. However, when the fruit begins to soften, these compounds dissipate and anthracnose is able to develop.

Initially, small, light brown spots develop on the skin. These rapidly enlarge and change colour to dark brown or black. Centres of the spots may be slightly sunken. If a fruit is kept in a moist atmosphere, pink spores will develop on the spots. The smaller spots may rapidly coalesce and spread into large areas of rot that may cover the entire fruit surface. The dark rot usually penetrates deeply into the flesh in a hemispherical pattern.

Source of infection and spread

Large numbers of fungal spores are produced in the tree on dead twigs, leaves and fruit. Here they can often be seen as pink spore masses. The spores are spread through the orchard during periods of wet weather, overhead irrigation and heavy dews.

After landing on undamaged fruit surfaces, spores germinate and penetrate the skin with an infection peg. The germination/infection period requires about 48 hours of free surface water from rainfall, irrigation or dew. After this period, the fungal infection is then fairly resistant to adverse wet or dry weather conditions. The infection peg, called an appressorium, remains dormant until the fruit begins to ripen. Throughout this stage, there are no visible signs of disease, but the fruit holds a latent infection. Fruit are susceptible to infection through all stages of development.

Where field infection occurs through damaged areas on the fruit such as insect stings, the process is slightly different. Here, infection occurs, but continues to develop through a 'localised' pseudo-ripening effect around the damaged tissues. As a result, the fungus completes its development through to localised rotting and the production of spore masses for a new cycle of infection.

Management of the disease

Management of the disease involves two main strategies:

- Protection of fruit in the field by a program of regular preventative fungicide sprays to maintain a protective film of fungicide on the fruit throughout its development.
- Once-only postharvest treatment of fruit with fungicide to reduce the latent infections in the skin and prevent the development of postharvest rotting. This is only effective where a good preharvest spray program has been in place.

Field management

- Spray trees with a registered fungicide from fruit set to harvest. The recommended spray interval is 14 days during prolonged wet weather and 28 days under clear weather conditions.
- Ensure good ventilation and rapid drying of the foliage by pruning lower limbs so that the canopy is well clear of the ground.
- Prune out dead twigs and branches before flowering. Also remove infected fruit which have not fallen from the tree.
- Control insect pests such as fruitspotting bugs and Queensland fruit fly that provide damage sites for field infection.
- During harvesting, handle fruit carefully to avoid damaging the skin.

Postharvest management

- Keep harvested fruit out of direct sunlight to prevent overheating.
- Treat fruit after harvest with a registered fungicide.
- Where the time from harvest to delivery at the wholesale market exceeds two days, pre-cool fruit promptly to remove field heat. Hold fruit at appropriate storage temperatures until despatch:
  - green mature fruit: 4 to 5°C for Hass (maximum four weeks) and 6 to 8°C for other varieties (maximum two weeks);
  - ripening fruit: no lower than 12°C;
  - near ripe fruit: 2 to 5°C (maximum 10 days).

  Lower storage temperatures may cause chilling damage.
- Temperature has a critical effect on anthracnose development during fruit ripening. Once fruit starts to ripen, temperatures of 24°C and above will greatly accelerate development of the disease. Ripen fruit at 16 to 18°C using ethylene.

Although current management of anthracnose relies heavily on pre- and postharvest fungicides, research in progress indicates that future management of the disease will centre around an integrated program including rootstock selection, nutrition and the use of biocontrol agents, as well as fungicides.

Managing crop production: Pesticide application and safety

Although there have been significant advances in the use of integrated pest and disease management systems in avocados, current technology still depends heavily on the use of chemical pesticides.

There are two important aspects of responsible use of chemicals. The first is efficient application, so that the effect of each spray on the target is maximised, thereby reducing the number of sprays that may be necessary. The second is safety in use and application, so that any impacts of chemicals on operators, farm workers and the community are minimised.

Basic understanding of spray application

Spray application is a somewhat involved and complex issue, but it essentially revolves around two important issues:

- Knowing and understanding the target.
- Getting the chemical to the target and depositing it in such a way to achieve maximum coverage.

Knowing and understanding the target

The first step is to clearly identify what you are targeting and understand what makes it easy or difficult to contact.

For example, anthracnose, latania scale and tea red spider mite are essentially stationary organisms, so these require very good coverage of the chemical to produce contact. On the other hand, fruitspotting bug and garden weevil move about on the tree and have a greater chance of coming into contact with the chemical.

Queensland fruit fly can be attracted from hundreds of metres away to a special food source, yeast autolysate. Their feeding behaviour appears to take precedence over its egg-laying behaviour. The food material is mixed with a chemical pesticide to form a bait spray, which attracts the fly and brings it into contact with the chemical. The bait spray only needs to be applied to a relatively small section of the tree to be effective.

Leafrollers cocoon themselves inside shelters made by rolling and webbing leaves and fruit together. This means they are difficult to reach with pesti-

cides, which work mainly on direct contact. In this case, contact can only be ensured by spraying before the insects develop their shelters, or by using a fumigant chemical in the spray to flush the insects out and into contact with the pesticide.

Getting the chemical to the target

Once you have identified and understood the target, the next step is to ensure the pesticide actually reaches it and makes maximum contact. There are four important issues.

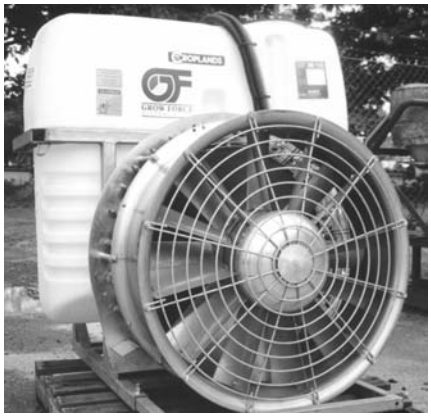
Droplet size. Experience has shown that the best coverage and penetration of tree canopies is achieved with droplets ranging from 50 to 120 micrometres in diameter (1000 micrometres [μm] = 1 mm).

Spray volume. Available machinery allows a wide range of spray volumes to be delivered, from 50 L/ha of mature trees for very low volume machines to over 2000 L/ha for high volume machines. To avoid wastage and run-off, the aim is to apply just enough volume to cover the target and, in some cases, wet it sufficiently to produce the pesticide effect. A good result is about 50 to 70 droplets of spray/sq. cm on both sides of the leaves and fruit. For latania and other scales where oil sprays are used, high volume sprays are required for a good result. The scales need to be sufficiently covered with the oil to effectively smother them.

Spray conditions. As sprays consist of water-based droplets, evaporation plays an important role in determining their fate. If the atmosphere is very dry and the droplets are small, the water carrier may evaporate before the pesticide has reached the target. Where small droplets are used (as is the case with most air blast and misting machines), sprays are best applied in the early morning, late evening or night, when evaporation rates are lowest.

Air movement. The main aim of pesticide spraying is to displace the air around the leaves and fruit and replace it with air laden with chemical droplets. This requires air movement; the larger the droplets, the larger and more turbulent the airstream required. For example, large droplets (more than about 150 micrometres in diameter) will drop to the ground fairly quickly unless carried in a large airstream. The main problem in effectively spraying a large tree like an avocado lies in getting spray to the top of the tree and inside the canopy. A combination of small droplets and airstream movement is most efficient in achieving these goals.

For avocados, when the two issues of target pests/diseases and spray coverage are considered, air blast machines appear to provide the best balance of performance and flexibility.



Air blast machines

Air blast machines are designed to transport to the target small droplets produced by hydraulic nozzles in an airstream produced by a fan (Figure 30). The machines are generally operated at low spray volumes (500 to 1000 L/ha of mature trees), but can be used in high volume mode for problems like latania scale.

***Figure 30**. A typical three-point linkage air blast sprayer*

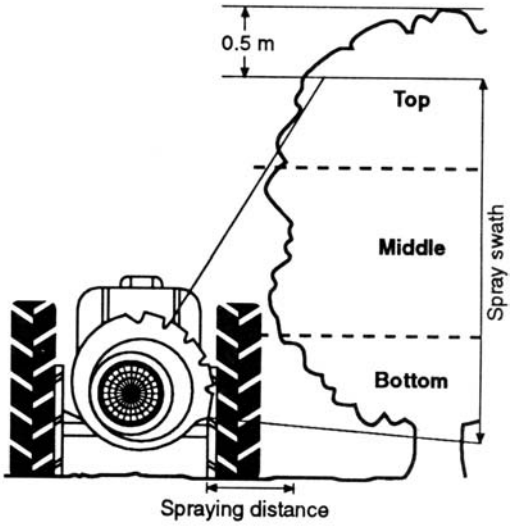


***Figure 31**. Positioning of machine to achieve effective spray swath*

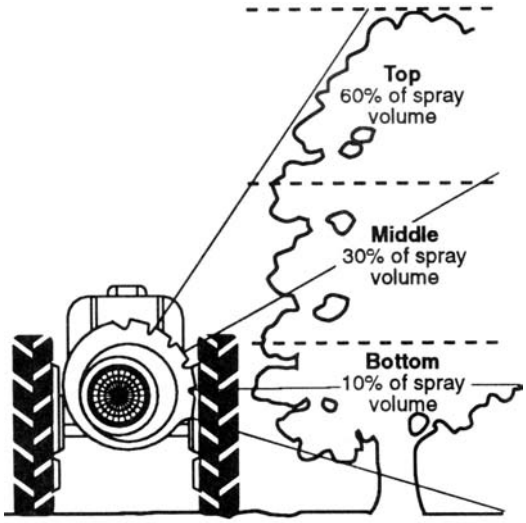


***Figure 32**. Nozzle selection and arrangement to achieve appropriate spray volume proportions*

Here are some key factors in the efficient operation of air blast machines:

- Set up the machine to spray the largest trees in the orchard.
- If trees are over 3 to 4 m high, use the machine in single-side, air-delivery mode only, as this provides greater spray penetration.
- The airstream outlet should be a minimum of about 1 m from the edge of the canopy to allow for unobstructed air flow (spraying distance in Figure 31). This means the trees must be pruned to maintain a suitable alley width.
- The spray swath (from lowest to highest nozzle) should cover the full height of the tree, but not waste spray in the air space above the tree. Adjust the spray swath so that the top of the airstream is about 0.5 m from the top of the tree (Figure 31).
- Select and arrange nozzles so that the largest proportion of the spray volume is directed towards the top of the tree (Figure 32).
- Operate the machine at a ground speed of 2 to 4 km/hr. The exact speed will depend on tree size, canopy density and the air volume produced by the sprayer. To ensure coverage is adequate, fill the sprayer with water and check spray penetration at several speeds within the range. To do this, hang strips of water-sensitive paper in the tree canopy. When a level of suitable spray penetration has been determined, measure the actual ground speed by the formula in Table 18. Don't rely on the tractor speedometer.
- Keep trees no more than about 5 to 6 m high, to facilitate coverage in the top part of the tree.
- Spray volume per tree needs to be sufficient to provide adequate coverage. It depends on tree size and canopy density. In general, large mature trees require 400 to 700 L/ha (5 to 10 L/tree). This should be effective against all pests except scales. To ensure spray volume per tree is adequate, the sprayer needs to be calibrated. A process for this is shown in Table 18.

***Table 18**. Sprayer calibration to determine output*

Process
1. Check that the pressure gauge is working properly.
2. Check spray nozzles and replace worn ones. Measure nozzle output for 30 seconds, replacing any nozzles that vary by more than 10% from the manufacturer's specifications.
3. Fill the tank, set the pressure and operate the sprayer for a minute or so in a stationary position to get all lines full.
4. Stop the sprayer and refill the tank to the top or a pre-determined mark.
5. Operate the sprayer in a stationary position for one minute.
6. Measure the amount of water required to top up the tank again to the top or the pre-determined mark. This is the sprayer output in L/minute.
7. Check ground speed. Mark out a distance of 100 m. Select a gear to produce an operating speed of about 2 to 3 km/hr. With the sprayer operating, time the travel over the 100 m. From this, calculate the actual speed in km/hr from the following formula: $\frac{\text{distance (m)} \times 3.6}{\text{time taken (sec)}}$

8. Calculate spray volume in L/ha from the following formula:

$$\frac{600 \times \text{sprayer output (L/min)}}{\text{row spacing* (m)} \times \text{speed (km/hr)}}$$

   * Assumes both sides are being sprayed. For a single sided sprayer, divide row spacing by 2.

9. Divide spray volume by the number of trees per hectare to calculate the volume applied per tree. If less than the desired amount, travel at a slower ground speed and re-calibrate. If more than the desired amount, increase ground speed and re-calibrate.

10. Regularly check nozzles, pressure gauge and spray volume to ensure desired spray volume continues to be applied.

Bait sprayer

Figure 33. *Bait sprayer in use in a passionfruit orchard*

The bait sprays for fruit fly control are applied with different equipment. This is because small volumes of spray are being applied (up to 30 L/ha), the spray is being directed to the lower part of the canopy only, and the spray is best applied as a coarse spray rather than the fine spray required for other pests and diseases.

A suitable sprayer can be built on a fat-track motorbike with coarse nozzles mounted either side (Figure 33). The sprayer is best operated at a pressure of about 350 kPa delivering about 50 to 100 mL/tree.

Make sure the sprayer has adjustable nozzles so that the spray band can be positioned to suit the changing height of the leaf canopy.

Pesticide safety

Major precautions

All pesticides should be considered potentially hazardous. However, if simple safety precautions are taken, these hazards can be minimised or even eliminated. Here are the main precautions:

- Always read the label before handling.
- Obtain and study the Material Safety Data Sheet (MSDS) for each chemical you use (chemical suppliers should be able to supply copies). File these in a safe place so they can be quickly referred to in case of emergencies.
- Use pesticides only as directed.
- Follow all safety directions, including the use of safety equipment.
- Know the various ways pesticides can enter the body.
- Keep all chemicals in a secure location.
- Store chemicals in their original containers only.
- Dispose of empty containers immediately in the correct way.

Pesticides and the environment

Always think of the environment when you are applying pesticides. There are four main areas where pesticides can pose a threat to the environment.

Spray drift is generally the result of incorrect sprayer type, set-up or calibration, or spraying during inappropriate weather conditions. Calibrate your sprayer at least annually.

Excessive spray run-off is generally caused by similar factors to spray drift.

Inappropriate disposal of excess pesticide (both concentrate and dilute) and empty pesticide containers. There are documented methods for the safe disposal of these products. These can vary from state to state and some are covered by legislation. All growers should be aware of their local disposal regulations. Do not use empty pesticide containers for any other purpose.

Poor location of your pesticide storage shed, fill up and wash down areas. Pesticide users need to think about what would happen in a spillage. A common example of a potential hazard is where these facilities are located next to a water source. While convenient, the risk of contamination of the water source after a pesticide spillage is very high. If chemicals need be stored close to a water source, ensure precautions are in place to handle an accidental spillage.

How pesticides enter the body

Pesticides can enter the body in three ways.

Absorbed through the skin (dermally). Liquids are particularly hazardous and repeated skin exposure may lead to acute poisoning (short-term and severe), especially when handling the pesticide concentrate (for example, when mixing). Long-term exposure to drift from sprays or recently sprayed plants may also lead to chronic poisoning (continues over a long time). Dermal absorption occurs when inadequate protective clothing is worn.

Inhaled. This is a particular problem with dusts and fumigants. Inhalation may lead to both acute and chronic poisoning. Inhalation poisoning occurs when a suitable, properly maintained respirator is not worn.

Swallowed (ingestion). Children under the age of five are historically most at risk from swallowing pesticides. The danger results mainly from inadequate storage security or improper disposal of empty containers.

Chemical accreditation

Growers must be able to demonstrate that they are using pesticides safely and responsibly. One way is to obtain accreditation under the ChemCert Training system.

ChemCert is a special farm chemical user training course available throughout Australia. Participants undergo the training, complete an assessment at the end of the course and are issued with a statement of accreditation by their state ChemCert organisation. The accreditation is valid for five years.

ChemCert contacts
Section 6 page 14

Besides demonstrating responsible and safe use of chemicals, ChemCert accreditation offers other significant benefits. For example, throughout Australia, the pesticide endosulfan can only be supplied to or used by an accredited person. In some states, some other pesticides cannot be bought without current accreditation. ChemCert accreditation will also assist in

the documentation of a quality assurance program.

In some states, TAFEs and other organisations offer training in chemical use, application and safety. Some of these courses are accredited for ChemCert. For example, in New South Wales, NSW Agriculture and TAFE NSW offer the SMARTtrain chemical program. Contact your state department of agriculture or local TAFE for details of local courses.

Chemical and spraying information
Section 6 page 14

IMPORTANT—USE OF ENDOSULFAN

It is a legal requirement that all growers using the pesticide endosulfan maintain a record of each application. It is the responsibility of the grower to collect (either directly or from a person on his/her behalf) and record all of the information required in a special Endosulfan Spray Record*. The record requires the completion of information on the farm and the name of the person applying, crop and pest details, weather conditions at application, and detailed application information.*

Growers may use their own computer-generated forms or special forms available from the National Registration Authority (NRA) or other chemical agencies.

Managing crop production: Topworking trees

The avocado varieties grown will change with time. This may be because of changing consumer preferences, or the availability of new varieties with improved marketing and production characteristics. When this happens, growers can replant with new trees or topwork existing trees to the new varieties. Topworking has the advantage of a shorter time to commercial yields.

Equipment needed

- *chainsaw*
- *water-based acrylic paint*
- *paint brush or sprayer*
- *grafting knife*
- *grafting tape*
- *white plastic bags (75 mm x 100 mm)*
- *white paper bags (75 mm x 100 mm)*
- *twist ties*
- *secateurs*
- *pruning saw*
- *1.5 to 2 m stakes*

Background

Topworking is a term used to describe the process of changing the variety on a large well-established tree. It involves cutting the tree back and either grafting a new variety onto shoots emerging from the cutback trunk and branches, or bark grafting directly into the stumps of the trunk and major limbs. The main advantage of topworking compared to replanting new trees is the shorter time taken to reach commercial production—about 18 months compared to three years for nursery trees.

Already popular in California, Israel and South Africa, topworking is now of increasing interest to Australian growers. This is because many growers want to improve orchard productivity and take advantage of newer varieties with more desirable characteristics. For example, many growers in south-east Queensland are seeking to replace their Fuerte trees because they no longer enjoy the advantage of early season markets and the variety has a range of crop management problems.

Topworking is not advised if trees are unhealthy, particularly if Phytophthora root rot is the cause, or where the rootstock is poor or highly variable. In these cases, it is best to remove the old tree and replant. Where the tree is showing mild symptoms of root rot, ensure phosphonate fungicide injections have been applied in the season before topworking.

Growers should be able to topwork trees themselves. However, propagators with topworking skills may be available in some areas. Before attempting topworking, growers are advised to read widely about the practice and, if possible, speak to other growers who have had some experience with it.

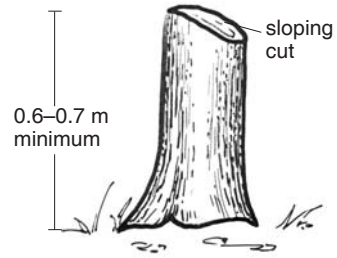


Figure 34. *The first step—cutting the tree down to a stump*

Figure 35. *Shoots appearing from the stump*

Figure 36*. Retain four shoots to grow to grafting size*

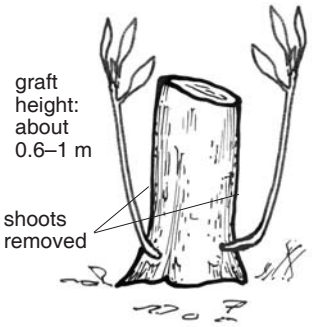


Figure 37*. Shoots ready for grafting*

The procedure

The procedure described here is topworking back onto newly grown shoots, as this is considered the best option for most growers. Bark grafting requires more skill and is best left to professional propagators.

1. The best time to start topworking is soon after harvest. In south-east Queensland, this is the end of August. Use a chainsaw to remove the existing tree canopy, leaving a stump about 0.6 or 0.7 m high, with a slightly angled cut so water will not pool on the cut surface (Figure 34). Ideally, reduce the tree to the original rootstock, but this may not be possible. Cutting any lower than 0.6 m may result in the tree dying from lack of reserves and/or being more prone to disease infection.
2. Seal the stump using white water-based acrylic paint to protect the stump from disease. Lightly brush or spray the rest of the stump with watered-down paint, ensuring it can still breathe. The paint helps to protect the stump, as avocados are extremely sensitive to heat and sunburn. The paint may need to be periodically reapplied.
3. Keep the stump and roots healthy. Ensure the soil has sufficient moisture, but don't over-water. Cut water back significantly from what was needed when the tree had vegetative growth. Shoots will start to appear at various points on the stump (Figure 35).
4. As shoots grow, select about four of the most vigorous shoots emerging near the base of the stump as close as possible to the ground, preferably no higher than 30 cm (Figure 36). Ensure shoots are retained on both sides of the stump, preferably shoots that are growing in the direction of the hedgerow, rather than out into the alley space.
5. Grafting can start when the retained shoots reach a suitable size for grafting (Figure 37).
6. The process then involves selecting budwood from the most productive healthy trees available and grafting it onto the two most vigorous, upright, strong shoots. Where possible, use a shoot on either side of the stump to maintain existing orchard row uniformity. Keeping topworked trees within the hedgerow helps ensure easier orchard management in the future (Figure 38). The other two shoots can then be removed. The reason for retaining four shoots to this point is to provide some choice in the selection of shoots for grafting. Although only one grafted shoot is ultimately required, two shoots are grafted as insurance against one being lost in a wind storm.

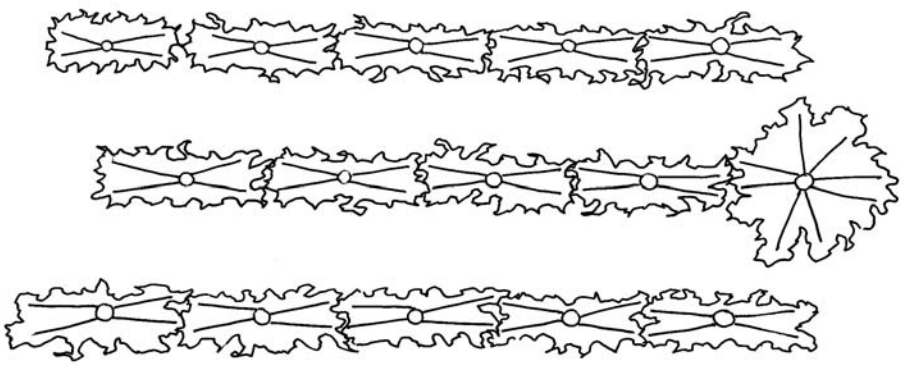


Figure 38*. Select and graft shoots growing in the direction of the hedgerow rather than those growing out into the alley space (tree at right) - plan view*

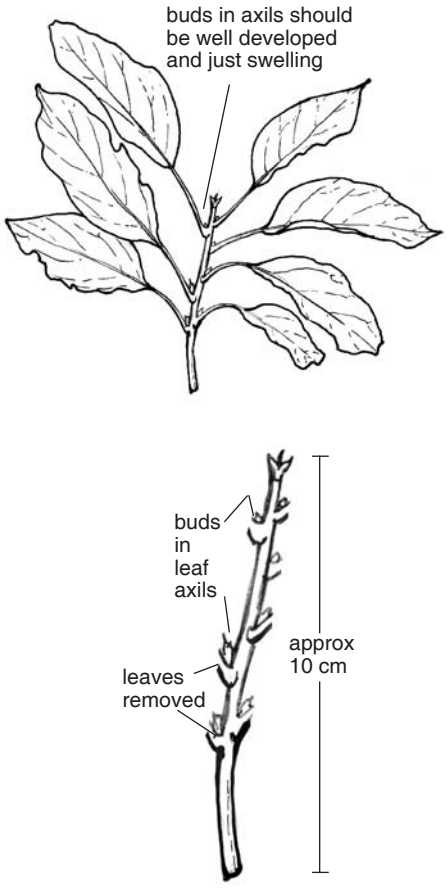


Figure 39. *Top: mature terminal growth selected for budwood. Bottom: budwood section with leaves removed*

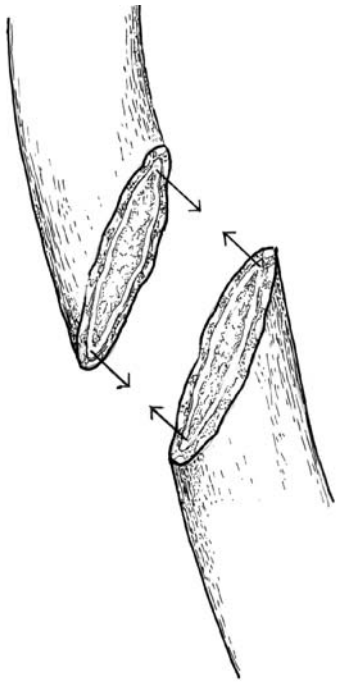


Figure 40*. Matching the cambium layers of the shoot and budwood is important*

It is important to select budwood from trees that are healthy and disease-free and have proven production capacity. Avoid using trees solely on having the most vegetative growth and therefore a better supply of suitable budwood.

Grafting

Avoid grafting in extreme weather conditions such as high humidity or intense heat or cold. Grafting in early autumn is recommended (April to mid June in south-east Queensland). Hygiene is critical. When collecting budwood, disinfect secateurs between trees by wiping with a rag dampened with methylated spirits. This ensures you do not accidentally spread disease between trees. Use a disposable rag such as a Chux wipe.

1. Select budwood from mature terminal growth with terminal bud or flower buds clearly visible, prominent and just swelling. Trim 10 cm sections and snip off the leaves, leaving short stems. Leave the buds (Figure 39). It is best to collect budwood early in the morning of the same day as grafting, or late afternoon for the next day of grafting. Budwood can be kept for up to two weeks in a refrigerator at 5 to 7°C. After collection, place the budwood in a small esky containing an icepack, or wrap in a damp rag or damp newspaper and place in a plastic bag.
2. The budwood can be grafted onto the selected shoots using whip grafts or cleft (wedge) grafts. The choice depends on the thickness of the budwood and the shoot.

   Whip grafting is simple, easy and quick. It is suitable when the thickness of the rootstock shoot and budwood are similar. The aim is to ensure the best possible match between the cambium layers of the two cut surfaces so the graft can take (Figure 40).

   Slice off the ends of the budwood and the shoot at an angle, creating an oval surface between 2.5 and 5 cm. Match the surfaces together (Figure 41), ensuring as close a match as possible between the cambium layer of the shoot and the budwood, and bind with grafting tape. Ensure there are no air gaps or open spaces.

   Cleft or wedge grafting is beneficial when the rootstock shoot is bigger than the budwood and it is impossible to match the cambium layers effectively. Slice both sides of the end of the budwood to form a wedge. Split the end of the shoot and insert the wedge into the cut, ensuring as close a fit as possible between at least one of the cambium layers of both shoot and budwood (Figure 42). Bind with grafting tape, ensuring no air gaps or open spaces.
4. Cover the new graft to protect it from the heat and drying out (Figure 43). Place a small white plastic bag over the grafted shoot, extending past the graft, and seal with a twist tie below the graft. The twist tie should be firm enough to keep the bag secure, but loose enough to allow excess moisture to escape. Cover this with a small white or brown paper bag, which has been pierced four or five times to allow heat to escape. Seal this with a twist tie below the graft. Leave both bags in place, loosening ties on the plastic bag after two to three weeks to ensure buds or leaves can grow unhindered and no excess moisture is building up (a little fog or mist inside is fine).

Figure 41. *Whip grafting showing the budwood and shoot about to be brought together*

Figure 42*. Wedge or cleft graft*

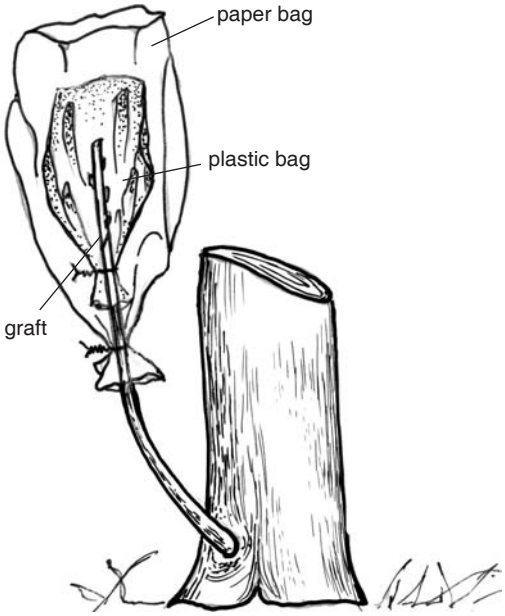


Figure 43*. Covering the graft with a plastic and then paper bag (only one grafted shoot is shown for convenience in this illustration)*

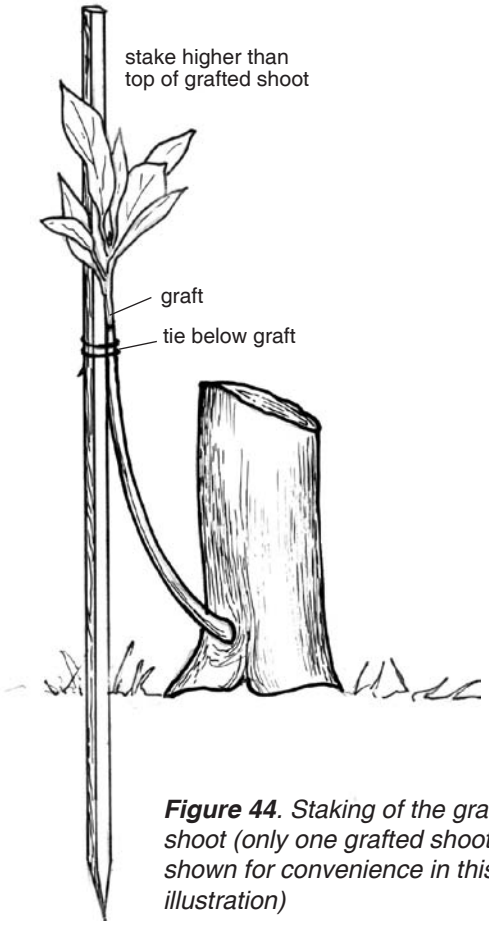


Figure 44*. Staking of the grafted shoot (only one grafted shoot is shown for convenience in this illustration)*

5. Inspect after three weeks and remove the tie on the plastic and paper bags to allow for growth, but leave the bags in place. Remove the plastic bag two to three days before removing the paper bag—about three to five weeks after grafting. Remove the paper bag on an overcast day or late in the afternoon.
6. After the bags have been removed, the grafted shoot needs to be staked to protect it from wind and other physical damage, including birds landing on it. This is necessary for the next six to eight months until it is strong enough to support new growth. Insert a 1.5 to 2 m stake into the ground next to the graft. Tie the bottom rootstock section of the shoot onto the stake below the graft so it doesn't move in the wind (Figure 44). When the top section of the graft has begun to grow leaves (about a month after grafting), tie the top portion to the stake as well. The stake should be about 50 cm higher than the top of the new shoot. Use grafting tape or other flexible material to tie the shoot to the stake.
7. Keep removing any new shoots periodically, as they will compete for resources with the grafted shoots.

Critical success factors

Some critical success factors in topworking are:

- Good orchard hygiene at the budwood grafting stage to ensure diseases are not transmitted to the topworked trees.
- When grafting, matching as much of the cambium layer on rootstock and scion as possible to ensure the new tree has a strong and healthy water conducting system.
- Carefully looking after the grafted shoot to ensure there is no damage that may affect subsequent growth.
- Using vigorous rootstock shoots to provide the best opportunity for successful topworking.
- Monitoring the tree during topworking to ensure water and nutrients are appropriately adjusted and new growth is protected against pests and diseases.